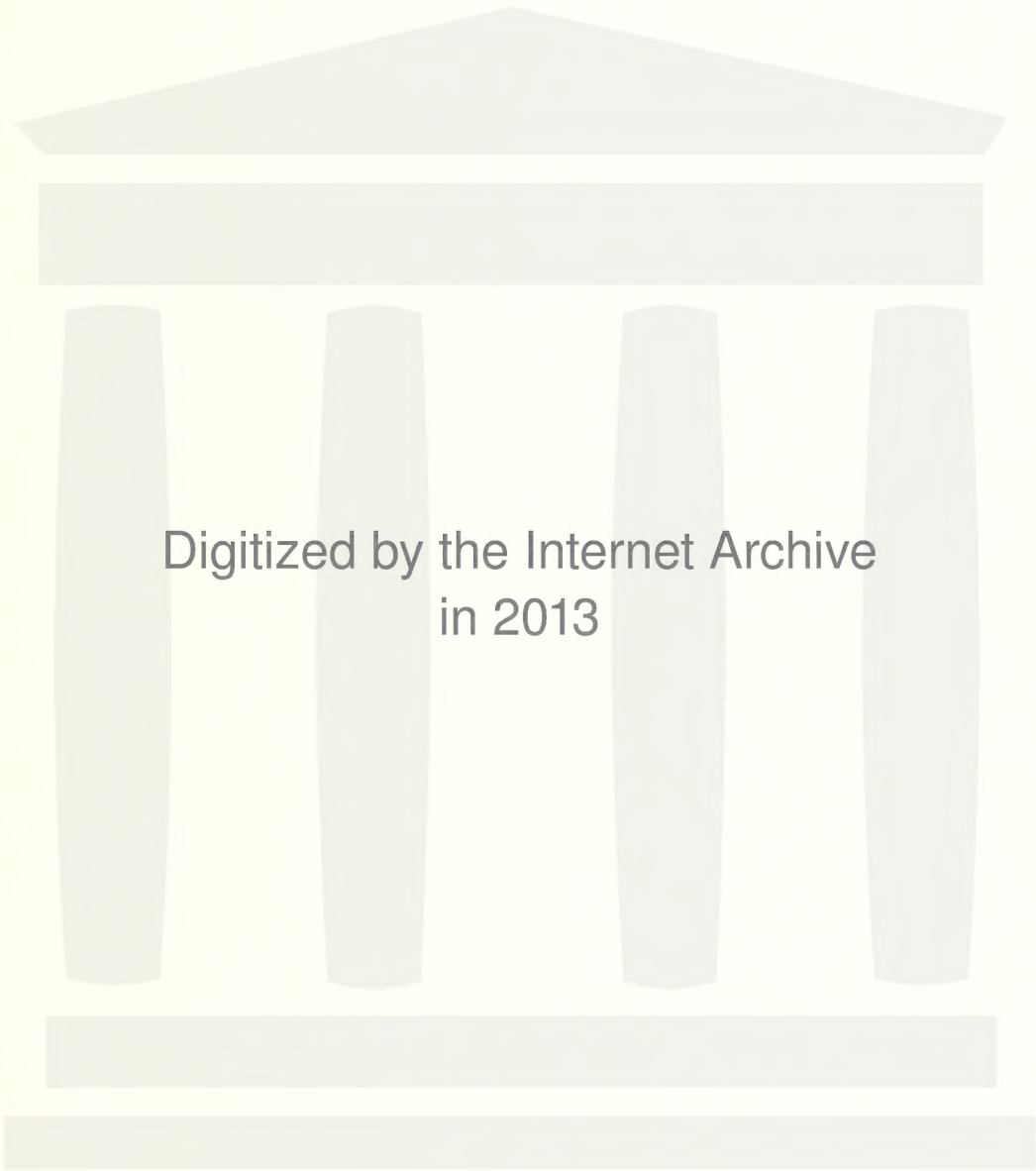
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Report INT-204

July 1986

A Climatic Handbook for Glacier National Park—with Data for Waterton Lakes National Park

Arnold I. Finklin

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RESEARCH SUMMARY

This publication presents climatic details for the Glacier National Park-Waterton Lakes National Park area in northwestern Montana-Alberta; data and analysis mainly cover the Montana area. The content, including numerous tables and graphs, is intended to provide information to aid fire management planning and other wildland resource activities. Data are summarized and analyzed from year-round climatological stations, fire-weather stations, and additional sources. Weather and climatic elements are examined individually. In addition, combinations of temperature, relative humidity, and windspeed data are included for the fire season.

The data show some of the elevational and other topographic effects identified with mountainous areas. Despite large differences in average values, the data also show a general similarity—within the park boundary—in the normal annual regimes of the climatic elements; an exception occurs with windspeed. For example, November, December, and January are the heaviest precipitation months within most of Glacier Park, even though normal annual precipitation ranges from about 23 inches (585 mm) to 100 inches (2 500 mm) or more. July and August are normally the driest months of the year. The pattern differs—with relatively light winter (and annual) precipitation—on the plains immediately east.

High interstation correlations are found for afternoon temperatures; correlations are moderately high for precipitation amounts. A persistence tendency is indicated between late spring (May-June) and summer (July-August) maximum temperatures and precipitation, relative to normal, but not between the individual monthly values. Climatic trends or fluctuations during this century, examined by running means, show recent July-August 11-year rainfall amounts well above normal, while September-October was abnormally dry. Fire-weather statistics of afternoon temperature and relative humidity, if based on these recent summers, give a cooler and more moist picture than that of the longer term. Our climatic findings do not support some published explanations for the historically greater fire activity on the west side of Glacier Park. The east side, overall, has about as much precipitation accumulation and thunderstorm occurrence as the west side.

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Intermountain Research Station
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INTRODUCTION

To its visitors, Glacier National Park, MT, offers a closeness to the marvels of nature. Although its alpine terrain features give the park its special character, the flora and fauna are also major aspects of Glacier. Here and in other lands under its administration, the U.S. Department of the Interior, National Park Service, is given the mission of preserving the area's natural state (in addition to providing for public use). In recent years, Park Service policy (Kilgore 1976) has come to recognize the historic, natural role of fire in shaping and maintaining the diversified wildland ecosystems. Fire management now seeks to allow some natural, lightning-caused fires to burn (within prescribed limits) and also to utilize planned ignitions—in contrast to the earlier efforts toward total fire suppression. Implementation of this new policy has been slow in Glacier Park, because of necessary concerns about public acceptance and safety, and lack of specific information to guide decisions. Interest has thus far concentrated on the more fire-prone west side of the park. A prescribed burn was successfully conducted near Polebridge in 1981; a second one in 1983.

Data needed for fire management are being obtained by research concerning fire history (Barrett 1983), fire-susceptible terrain (Key 1984), and prescribed burning. Cooperating with Glacier Park personnel in these studies has been the U.S. Department of Agriculture, Forest Service, at its Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, MT—together with Systems for Environmental Management, Missoula. Data used for planning also include those of weather and climate—for example, in establishing seasonal limits for prescribed burning. Climatic data can, in addition, establish a baseline for use in evaluating fire effects. These effects, such as postfire vegetative response, may be strongly influenced by the normal or abnormal extent of weather conditions in the ensuing months and years.

This publication, termed a handbook, is intended to fill some of the climatic data void. Though prepared largely as a reference for fire managers, the handbook includes data for other management and research activities within the park and adjoining areas. Thus, the content may also have applications relating to forest ecology, wildlife, hydrology, recreation, and to rangelands just east of the park on the Blackfeet Indian Reservation. The data coverage includes Waterton Lakes National Park, AB, part of Waterton-Glacier International Peace Park. The main coverage available, however, is for Glacier Park and adjacent Montana.

A brief climatic description of Glacier National Park, aimed toward the general public, was prepared by Dightman (1967a). The climate of Waterton Lakes National Park has been described by Poliquin (1973). In neighboring Rocky Mountain areas, Dirks and Martner (1982) present climatic details for Yellowstone and Grand Teton National Parks; they also refer to more extensive University of Wyoming project reports. A climatic report by Janz and Storr (1977) covers Yoho, Kootenay, Banff, and Jasper National Parks in British Columbia and Alberta. Local topographic and site effects on summer climate in a forest area southeast of Banff are described by MacHattie (1966, 1968, 1970).

The present handbook includes climatic details for the fire season, to 10-day resolution, together with the year-round pattern. In addition to graphs and tables appearing within the text, detailed summary tables and data listings are given in an appendix. The scope does not cover related or derived factors such as fuel moisture and fire-danger indexes. Because our objective is to present climatic information, detailed physical or technical explanations have been left to references. Sources for elementary background in weather and climate include Schroeder and Buck (1970); Critchfield (1974); Landsberg (1958); Reifsnyder (1980).

In discussing the climatic elements over the course of a year, this report will mostly follow the format of treating the elements individually. A description combining the elements by seasons is, however, included in the section, "Condensed Summary of the Climate."

DESCRIPTION OF THE AREA

Physical Features

The location of Glacier and Waterton Lakes National Parks is shown in figure 1. Covering a total area of 1,143,000 acres (462 500 ha) near and astride the Continental Divide and the Canadian-United States border (49th parallel of latitude), this land will also be referred to as Waterton-Glacier—the name of the International Peace Park established in 1932. Glacier, comprising 1,013,000 acres (410 000 ha), became a National Park in 1910; Waterton Lakes, with 130,000 acres (52 500 ha), began its preservation as a "Forest Park" in 1895 (Buchholtz 1974).

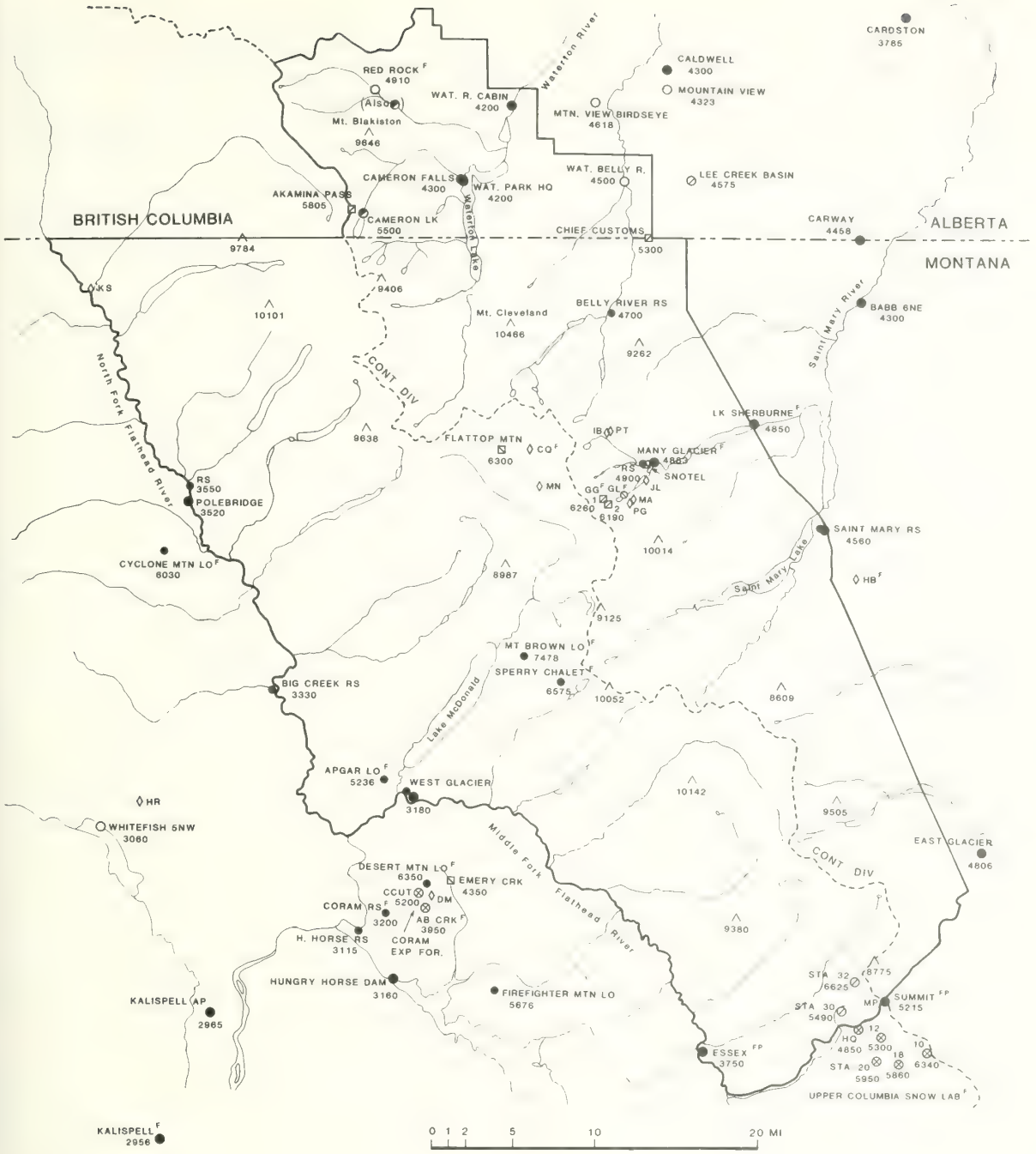


Figure 1.—Location of Glacier and Waterton Lakes National Parks (Waterton-Glacier International Peace Park) (stippled area), together with surrounding weather stations mentioned in text.

The basic geological history of this area starts with the Precambrian layers of limestones, mudstones, and sandstones—formed from sediments deposited in a sea-filled trough (called the Belt Sea) and intruded by magma. Subsequent events include: the uplift and folding of these layers during the mountain-building period that began about 75 million years ago; a fracture initiating the Lewis Overthrust Fault, on which a huge slab of rock ultimately slid about 40 miles (65 km) eastward and covered rock 1 billion years younger; and the processes of erosion by water and (within the past 2 million years) by glaciers, shaping the terrain to its present appearance. (See Dyson 1966, 1967; Alt and Hyndman 1973.)

The main drainage features and elevations of the highest peaks are shown in figure 2. No attempt is made to depict the complex and steep terrain contour pattern—available from U.S. Department of the Interior, Geological Survey, topographic maps. Elevations within Glacier Park range from about 3,110 ft (948 m) a.s.l. (above sea level) at the Middle Fork-North Fork Flathead River confluence to 10,466 ft (3 190 m) atop Mount Cleveland (fig. 3). Within Waterton Lakes Park, elevations range from just under 4,200 ft (1 280 m) to 9,646 ft (2 940 m) atop Mount Blakiston. The Continental Divide trends generally from northwest to southeast. It is formed mostly by the Lewis Range, which runs the length of the park from east of Waterton Lake, but also by the smaller Livingston Range (farther west) in the northern portion. Waterton Park lies entirely on the east side of the Divide, while 60 percent of the Glacier Park land area is on the west side. Waterton-Glacier contributes to three major drainage systems, and a triple divide exists south of St. Mary Lake—separating flows into Hudson Bay, the Gulf of Mexico, and the Pacific Ocean.

The present glaciers, numbering about 50 in Glacier Park, are not remnants from the great ice ages (the last one ending about 10,000 years ago), but instead are believed to have originated about 4,000 years ago—following an intervening warm period. These lesser glaciers (and others since melted) apparently reached their maximum extent in the 1850's (Carrara and



- ● Regular climatological station, year-round temp. and precip. ○ Precip. only.
- ⊗ Other year-round station (for research, etc.), data mainly from recording charts
  - ⊘ Precip. only. ◐ Temp. only.
- ● Fire-weather or seasonal station. ⊘ Precip. only.
- ▨ Storage precip. gage, annual or semi-annual readings.
- ◊ Snow survey course. ▧ "SNOTEL" precip.

Figure 2.—Map of Waterton-Glacier Park area, showing drainage features (streams and lakes) and locations of stations providing data used in this report; symbols indicate type of station. Park boundary is shown by heavy line, Continental Divide by dashed line. Station elevations, and those of some high peaks, are given in feet. RS denotes Ranger Station; LO, Lookout; GG, Grinnell Glacier (gauges No. 1 and 2); GL, Grinnell Lake (elev., 4,925 ft). Two-letter abbreviations of snow courses are identified in table 27. Superscript F denotes formerly existing station (or station network); FP, former climatological station replaced by "Fischer-Porter" precipitation gauge.



Figure 3.—Mount Cleveland (capped by cloud), highest peak in Waterton-Glacier Park, at 10,466 ft (3 191 m); viewed toward southeast from Waterton Lake, September 1954.

McGimsey 1981). The drastic melting and retreat since that time, particularly during the 1920's and 1930's, is shown by the above authors and by Dyson (1966) and Johnson (1980). The largest glaciers, Grinnell and Sperry, now cover less than 300 acres (120 ha) each. Relation of this melting to climatic change or fluctuation was examined by Dightman (1952, 1956, 1967b). Although the rate of recession slowed considerably by 1950, and an advance of Grinnell Glacier was measured in 1951, the overall retreat continues.

Forests; Fires

Forests cover two-thirds of Glacier Park's land area (Kessell 1979). They occur mostly below an elevation of 7,000 ft (2 135 m)—limited by steep, rocky terrain as well as the climatic timberline. A contrast between forests on opposite sides of the Continental Divide has been noted by Habeck (1970), Robinson (1972), and Kessell (1979). The idealized elevational distribution of tree species (and forest community types) is complicated by local site differences and by the varying stages of succession following past fires.

Lodgepole pine (*Pinus contorta*) is widespread at lower and intermediate elevations. There is also much western larch (*Larix occidentalis*) and some western white pine (*Pinus monticola*) on the west side of Glacier Park. Climax species there include western redcedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*), found in the Lake McDonald vicinity—their easternmost extent in North America (Habeck 1968). Spruce (*Picea engelmannii* × *P. glauca* hybrid), Douglas-fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*) are climax species in other west-side areas. Ponderosa pine (*Pinus ponderosa*), apparently seral, occurs near Polebridge. Near the eastern park boundary, the lodgepole pine joins a mixture of prairie, aspen (*Populus tremuloides*) groves, limber pine (*Pinus flexilis*), and Douglas-fir. This eastern area is well grazed by wildlife such as elk and deer and (beyond the park) by livestock.

The highest elevation forests, below the alpine meadows and Krummholz vegetation, are dominated by subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and whitebark pine (*Pinus albicaulis*).

Fire has long had an important role in shaping and maintaining the forest ecosystems and their attendant diversity. In what is now Glacier Park, natural (lightning-caused) fires appear to have been much more frequent in the western portion than on the east side. A simple, partial explanation is that about two-thirds of the forested area is located on the west side. From the time of Glacier's establishment in 1910 through the year 1968, 90 percent of 525 reported lightning-caused fires occurred west of the Continental Divide, with close to 50 percent in the Lake McDonald subdistrict (O'Brien 1969). In the northwestern part of Glacier, a three-century fire history by Barrett (1983) revealed frequent and sometimes extensive underburns followed by occasional stand-replacing fires. The replacement-type fires appear to be more typical and significant, however, for the overall park area (personal communication from Carl H. Key, geographer, National Park Service). As much as 90 percent of Barrett's 60,000-acre (24 000-ha) study area has underburned within the past 56 to 95 years—but little since 1930, in an era of strong fire suppression

O'Brien (1969) found that 98 percent of Glacier's 1910-68 fires occurred between June 19 and September 19, with 30 percent in July and 51 percent in August. Nine percent (48) of the fires reached Class C size (10 acres [4 ha]) or larger, with 40 percent of these in July and 44 percent in August. Further analysis showed that 95 percent of the fires occurred at elevations below 7,100 ft (2 165 m) and about two-thirds on southern aspects. In a west-side area examined by Key (1984), lightning-ignition frequencies during 1910-82 indicated a greater susceptibility along certain ridge systems, at elevations below 4,000 ft (1 220 m), and on westerly and southwesterly aspects.

Memorable fires in Glacier Park include those in 1910, 1926, 1929, 1936, and 1967 (Robinson 1960; Habeck 1970). In the latter two years, fire swept eastward over the Continental Divide. The Heavens Peak Fire in August 1936, roaring down the Many Glacier Valley, completely or partially stripped about 7,500 acres (2 300 ha) (fig. 4). It burned the ranger station and other buildings but spared the hotel. A year earlier, a large fire affecting both Glacier and Waterton was stopped within about 1.5 miles (2.4 km) of the Waterton Park townsite. The new fire management policy of the National Park Service (Kilgore 1976) does, of course, continue suppression in such developed areas. Two large wind-driven fires in late August 1984, on or adjoining the southwestern and eastern edges of Glacier Park, ended a 17-year period of relative quiet.



Figure 4.—Many Glacier area, 1954, 18 years after the Heavens Peak Fire. (A) Along trail to Iceberg Lake; Mount Wilbur and Ptarmigan Wall in background. (B) At campground, lodgepole pine regenerating, looking west toward Mount Wilbur and Swiftcurrent Pass (topped by cloud bank at left). The fire swept over this pass from west side of Continental Divide.

STATIONS; DATA; METHODS

Locations and elevations of stations utilized in this report are included in figures 1 and 2. The stations in figure 1 are (or were) primary daily reporting stations, located mostly at airports. Those shown in figure 2, in Montana, are of two main types: (1) the year-round climatological substations ("cooperative" stations) of the National Weather Service (formerly U.S. Weather Bureau) and (2) the seasonal fire-weather (or fire-danger rating) stations of the Forest Service and National Park Service.

Detailed temperature and precipitation summary tables are presented for three of the cooperative stations—Polebridge, Summit, and West Glacier (fig. 5), all located on the perimeter of Glacier Park. Data from West Glacier have been observed near the present Park headquarters since 1918; a continuous record dates from 1926. The Polebridge data, mostly complete from 1947 to the present, are from the mercantile-post office location except for a 2-year period at the ranger station, 1.3 miles (2.1 km) to the north-northeast. Earlier, incomplete records from the ranger station go back to 1933. At Summit, observations were taken from 1935 to early 1979, with a few shifts in instrument location and many changes in observer. Precipitation measurements continue at Summit from a Fischer-Porter (punched-tape) recording gauge, which also transmits the data via satellite. Further station-history details, for these and other places, are given by U.S. Weather Bureau (1956) and Dightman (1967a).

The detailed summary tables were in part obtained through a data tape furnished by Dr. Joseph M. Caprio, State Climatologist at Bozeman, MT, and computer programs by Bradshaw (Bradshaw and Fischer 1984). The tape contained daily observations for the years 1949 through 1978. Additional data were tabulated from monthly and annual issues of "Climatological Data" State summaries for Montana and from U.S. Weather Bureau (1937, 1955, 1965); also from records furnished by the National Climatic Center, Asheville, NC. Tabulated data included those for the long-term climatic stations at Babb 6NE (6 miles NE) and Browning, both located east of Glacier Park in prairie or rangeland; the station at Browning was discontinued in 1980 (but replaced by a Fischer-Porter gauge).

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Figure 5.—Climatological stations on perimeter of Glacier Park; 1982 photographs except as noted. (A) West Glacier, near Park Headquarters. Thermometer shelter in center, precipitation gauges at left (Fischer-Porter recording type, with windshield) and right ("stick" type); snow-depth marker also visible. (B) Polebridge; thermometer shelter behind building housing mercantile and post office, precipitation gauge in open area to right of photo. (C) Summit, original station location near railroad; thermometer shelter in mid-background; 1947 photo from Corps of Engineers (1952b). (D) Present station near Summit (Marias Pass), Fischer-Porter gauge only; antenna to left of gauge for transmission of data via satellite. Thermometer shelter was located on the wooden platform during 1967-73.

Data for the fire-weather stations were accessed from tapes at the National Fire-Weather Data Library, Fort Collins, CO (Furman and Brink 1975), and from original forms filed through 1970 at the Intermountain Fire Sciences Laboratory. Summary tables again were obtained through the computer programs of Bradshaw and Fischer (1984). A few of the stations are pictured in figure 6. The fire-weather data in this report are based primarily on observations near 4 p.m. (1600) m.s.t., the standard prior to 1974; observations have been at 1 p.m. (1300) since then. As shown later, the change—made in accordance with new national standards—has resulted in some noncomparability with previous data.

As noted in figure 2, data were also obtained from stations in research areas. Locations include the former Upper Columbia Snow Laboratory, near Summit (or Marias Pass), where hydrometeorological data were observed during 1946-51 (Corps of Engineers 1949, 1952a,b,c,d); also the Coram Experimental Forest, south of West Glacier (Hungerford and Schlieter 1984). Other data include year-round records at St. Mary Ranger Station furnished by Jerry Ryder, Subdistrict Ranger, Glacier National Park.

Climatic averages for locations in Canada are, in part, from Atmospheric Environment Service (1982a,b,c). Special Waterton Park-area data were provided by David R. Graham, River Forecast Center, Alberta Environment, and Henry Turchanski, Atmospheric Environment Service, Environment Canada—both at Edmonton, and the report by Poliquin (1973). A copy of that report and other, first-hand information were furnished by Robert A. Watt, Warden Service, Parks Canada, Waterton Park.



A.



B.



C.



D.



E.

Figure 6.—Fire-weather or seasonal stations, Glacier National Park area; 1982 photographs except as noted. (A) West Glacier; site, more open, is about one-half mile northwest of year-round climatological station (fig. 5). Air-sampling equipment located on wooden platform. (B) Polebridge, at Ranger Station. Wind is, at present, measured with hand-held meter. (C) St. Mary; site one-fourth mile northwest of Ranger Station (and present year-round station). Napi Point and part of 1984 fire area in distance. (D) Hungry Horse, at Ranger Station (1984 photo). (E) Many Glacier, at Ranger Station; temperature and precipitation measurements only.

Data from Montana snow-survey courses, giving snowpack depth and water content, are from the Soil Conservation Service (SCS)(1975) and from monthly issues of that agency's "Water Supply Outlook." The SCS office at Bozeman, MT, through Phillip E. Farnes, provided "SNOTEL" (snow telemetry) data; these include cumulative water-year (October-September) precipitation, as at the station in figure 7. Streamflow, or runoff, data were obtained from bulletins of the U.S. Department of the Interior, Geological Survey (USGS), and from the USGS district office in Helena, MT. Additional data sources are identified later within the text.



Figure 7.—SNOTEL (snow telemetry) station at Many Glacier: site between Ranger Station and Swiftcurrent Lake. Snow course is along fence: snow pillow, precipitation gauge with windshield, temperature sensor (inside vane-type shield), and antenna mast are within enclosure.

The fire-weather and various climatic data were checked for errors and missing values. Using available backup sources and comparisons with adjacent stations, highly suspect daily and monthly values were corrected, replaced with estimates, or discarded. Estimates were made where possible for the missing values, which could be important in some cases (Finklin 1983a). Precipitation and snowfall measurements that occasionally covered a period of 2 or more days were apportioned to individual days. A backup source that aided in some of this editing was the monthly publication, "Hourly Precipitation Data," summary for Montana. That publication also provided data for continuing part of the record at Summit, referred to earlier.

Averages; "Normals"

Climatic averages in this handbook include those for a standard 30-year "normal" period (currently 1951-80), as adopted by international convention; the normal values are revised every 10 years. The 30-year length tends to balance out short-term variations, though a longer period is desirable for precipitation (World Meteorological Organization 1967). A 20-year data sample, however, has been used in fire-weather summary tables, governed by availability of data at an unchanged observation time. As already noted, this time was changed by 3 hours in 1974. Fire-weather averages are presented for 1951-80 in several graphs, adjusting the more recent data to the previous 1600 m.s.t. observation time, which better represented the extreme afternoon conditions.

Likewise, for comparability among locations, averages at stations with short periods of record have been adjusted to the 30-year period. The calculations, involving adjacent long-term stations, employ the "difference method" for temperature and relative humidity; the "ratio method" for precipitation (Oliver 1973; Finklin 1983a).

Even with 30 years of data, 10-day averages are apt to exhibit irregularity, largely accidental. Thus, smoothing is employed in some of the graphs—mainly a running 1-4-1 weighting factor applied to successive 10-day values.

Averages have been further adjusted in the case of maximum and minimum temperatures—to a 24-hour period representing the actual calendar day, midnight to midnight. This is the reference period used at the primary (airport) stations of the National Weather Service. The observed average maximums at cooperative and fire weather stations, with data for a 24-hour period ending near 1600 or 1700, are as much as 2 °F (1 °C) higher than those for the calendar day (Rumbaugh 1934; Finklin 1983a); see table 17 (appendix).

Another estimate or adjustment was involved in presenting averages of temperatures for a fixed higher elevation, or 6,000-ft (1 830-m) slope location, as in figure 22 in the "Temperature" section. In this case, the already-obtained normals from two short-record park area stations near this elevation were adjusted for compatibility with normals computed for the former stations at Mullan Pass, ID, Old Glory Mountain, BC (fig. 1), and Bangtail Ridge (near Bozeman, MT), and also for lookout stations. This took into account elevational and horizontal temperature gradients (shown in above section).

CONDENSED SUMMARY OF THE CLIMATE

Summary by Seasons

The seasons in the Waterton-Glacier area do not easily follow the widely used or standard 3-month divisions. Seasons adopted by the National Climatic Center in the United States are based on the 3 successive months that ordinarily have the highest and lowest average temperatures during the year. Thus, while June, July, and August comprise the standard summer season, June is more of a spring month in Waterton-Glacier—with weather more similar to that in May than to that in July-August. December, January, and February comprise the standard winter season. However, from considerations of below-freezing average temperatures and snowfall, winter in Waterton-Glacier may properly also include much of November and March. This leaves April, May, and June as the suggested spring season and September-October representing autumn.

Winter.—As thus defined, winter within Waterton-Glacier is, of course, normally cold and has copious precipitation (mostly snowfall). Precipitation amounts generally increase with elevation; they decrease rapidly with horizontal distance near and beyond the eastern edge of the park. November, December, and January are normally the wettest (snowiest) months of the year within most of the park boundary. December and January monthly totals average about 3 to 5 inches (75 to 125 mm) water equivalent at lower elevations and more than 10 inches (250 mm) on some of the high terrain. Over most of the park, the 5-month season accumulates between 50 and 60 percent of the annual total precipitation. The annual totals range from about 23 inches (575 mm) to more than 100 inches (2 500 mm) (in Glacier Park). At lower elevations, the period of continuous snow cover usually extends from sometime in November to sometime in April. Snow cover continues into May at approximately 5,000-ft (1 525-m) locations such as Many Glacier and Marias Pass.

January has the lowest monthly average temperature, with 24-hour means near 15 to 20 °F (−10 to −7 °C). Although severe cold can occur in the presence of Arctic airmasses, with 50-year extremes of −40 to −55 °F (−40 to −48 °C), winter temperatures average higher than those at locations farther east at the same latitude. The recurrent influx of mild Pacific airmasses is a primary modifying factor. January temperatures sometimes exceed 45 to 55 °F (7 to 13 °C), particularly on the east side, where the Pacific airmasses are further warmed under downslope ("chinook") wind conditions. Chinook windspeeds have been known to reach 100 mi/h 160 km/h). Overall, winds on the east side average about 13 to 15 mi/h (20 to 25 km/h) during winter, with the most frequent direction from the west or southwest. In the sheltered western valley areas, average speeds are at or near a minimum during winter, about 5 or 6 mi/h (8 to 10 km/h). This is a cloudy time of year, and sunshine is expected only 20 to 30 percent of the maximum possible time during November-January near and west of the Divide. Relatively sunny conditions occur near the eastern edge of the park.

Spring.—The warming trend during spring is occasionally interrupted by cool, stormy periods. Precipitation normally slackens in late winter and early spring but increases again in May and June. At many valley locations normal June amounts, mostly 3 to 4 inches (75 to 100 mm), approach or exceed those of December and January. In the drier areas just east and southwest of the park, May and June are normally the wettest months of the year. Heaviest 24-hour precipitation has occurred in June, reaching 6 to 7 inches (150 to 185 mm) at several stations on a day in 1964. June is the month of greatest flood potential, the combination of heavy precipitation and melting mountain snowpack bringing an annual peak in runoff. Thunderstorm activity becomes frequent in June, occurring on an average of at least 5 days near a given location. The lightning does not present much fire threat, however, because the forest fuels at this time are usually relatively moist.

The springtime warming is slowed during June, with afternoon temperatures held down by the showery conditions. Daily maximums in June average near 70 °F (21 °C) at lower elevations. Corresponding afternoon relative humidity averages near 45 percent. Last "killing" frost or 28 °F (−2 °C) minimum temperature occurs around mid-May to mid-June at lower valley locations. Average windspeeds on the east side of the park show a seasonal decrease from their winter maximum. In the western valleys, average speeds are at their highest in spring, though still a few miles per hour lower than on the east side. Although spring days are often cloudy, the percentage of maximum possible sunshine duration increases to about 50 to 60 percent.

Summer.—A large change in average conditions occurs in July. The short (2-month) summer, the main fire season, is usually a time of minimum cloudiness and precipitation within Waterton-Glacier. July precipitation totals average about 1.5 inches (38 mm) near the park edges; 2.5 to 3.0 inches (65 to 75 mm) over the park interior near the Continental Divide. August has slightly higher averages. In individual years, summer monthly totals at perimeter locations such as West Glacier, MT, may be near zero or as high as 4 to 5 inches (100 to 125 mm). Snowfall, limited to higher terrain and occasional years, has reached at least 9 inches (23 cm) at 7,500-ft (2 280-m) Mount Brown Lookout in late August. As in June, thunderstorms may be expected near a given location on 5 or more days during both July and August; this applies to both sides of Glacier Park.

July, normally slightly warmer than August, has average temperatures (24-hour means) near 60 to 63 °F (15 to 17 °C) in the lower valleys. The characteristic fair, dry weather results in large daily temperature ranges, so that July daily maximum temperatures average as high as 80 °F (27 °C) along the western edge of Glacier Park. Summer afternoon temperatures usually decrease with elevation, at an average rate of 4 to 4.5 °F per 1,000 ft (about 7.5 to 8 °C per 1 000 m). Summer nighttime temperatures, however, are often much lower in the valleys than on adjacent mountain slopes, due to temperature inversions. Fifty-year extreme maximum temperatures have reached close to 100 °F (38 °C) or slightly higher. The humidity on July and August afternoons averages about 35 to 40 percent in the valleys, but in extreme cases these monthly averages have been below 20 percent. Windspeeds during July-August are at an annual minimum on the east side and over the mountain terrain. Typical midafternoon winds in the park, away from sheltering timber, are between 7 and 10 mi/h (11 and 16 km/h), mostly from the southwest. But sustained winds of at least 25 to 30 mi/h (40 to 50 km/h), with stronger gusts, have been observed in extreme cases—most recently with the wildfires in August 1984. Sunshine during July-August averages about 70 to 75 percent of the maximum possible.

Autumn.—Autumn (September-October) usually comes early and is a distinctly transitional season. Average daily maximum temperatures for September fall 10 or 11 °F (6 °C) below those of August. The first "killing" frost or 28 °F (−2 °C) minimum normally occurs sometime in September, with average dates as early as September 2 at Polebridge, MT (August 21 in the higher valley at Summit, MT). Monthly precipitation totals

show an average seasonal increase within most of the park (a decrease in adjacent drier areas). The increase is only slight at many locations; a more pronounced increase begins in November (part of our defined winter season). October amounts are generally between 2 and 3 inches (50 to 75 mm). Snowfall is usually light during October in the west-side valleys, but particularly heavy storms occur in some years on the east side. At Summit, MT, as much as 61 inches (155 cm) snowfall has been measured in October; 30 inches (76 cm) on a single October day. September monthly snowfall here has reached 29 inches (74 cm).

October average windspeeds on the east side are already close to those of the winter season, while speeds are down to their yearly minimum in some west-side areas. Cloudiness is on the increase and sunshine percentage on the decrease during autumn but, again, a greater change occurs in November.

Summary by Individual Elements

Precipitation; Snowfall.—Normal annual precipitation (rain and melted snow) within Glacier Park ranges from about 23 inches (585 mm) to 100 inches (2 500 mm) or more. Topographic factors, including elevation, have a strong influence. Wettest areas are apparently in the central and northern interior, along or near the Continental Divide—particularly in cirque locations such as Grinnell Glacier, where precipitation is increased by upslope effects of both westerly and easterly winds. Driest areas are along the northeastern and northwestern edges, as at Polebridge. Available data indicate that the east side of Glacier Park receives about as much precipitation, averaged over the area, as the west side. Amounts are considerably lower on the plains a little farther east, where Browning averages 16 inches (400 mm).

December and January normally have the heaviest monthly precipitation over most of Glacier Park, with a secondary peak occurring in June. May and June are normally the wettest months on the adjacent plains and in the main Flathead Valley, as at Kalispell. A large decrease typically follows in July, the driest month within Glacier; a slight increase in August. Average amounts in summer exhibit small areal difference, as compared with those in winter months. At lower elevations, January normals range from 3 to 5 inches (75 to 125 mm); June, 3 to 4 inches (75 to 100 mm); July, 1 to 2 inches (30 to 50 mm). Between years, July-August totals at West Glacier have varied from 0.28 inch (7 mm) to 8.29 inches (211 mm).

Average annual snowfall along the park edge ranges from about 120 to 270 inches (300 to 680 cm) (heaviest near Marias Pass); the average probably exceeds 600 to 700 inches (1 525 to 1 775 cm) in favored mountain locations. Snowfall water content contributes more than 50 percent of the total precipitation at park elevations above 4,500 ft (1 370 m). Snow cover along the park edge usually persists from sometime in November to sometime in April or May; seasonal maximum depths here average mostly between 30 to 70 inches (75 to 175 cm). Mountain snowpack may linger into July in locations as low as 6,000-6,500 ft (about 2 000 m); depths average as much as 10 ft (3 m) or more on May 1.

Thunderstorms.—The main season of lightning (or thunderstorm) activity extends from about mid-May to mid-September. Storms around a given location (within about 20 miles [32 km]) occur on an average of 5 to 7 days per month during June, July, and August. The frequency appears to be similar on the west and east side of Glacier Park. About 50 percent of the July-August thunderstorms begin between 1200 and 1800 m.s.t. Lightning counts at Desert Mountain Lookout indicate a lightning activity level of 5 (as defined in the National Fire Danger Rating System) in about 20 percent of the storms.

Temperature.—Normal monthly "mean" temperatur at valley and canyon bottom locations, below 5,000 ft (1 525 m), range from about 15 to 20 °F (−10 to −7 °C) in January to 57 to 62 °F (14 to 17 °C) in July; 36 to 41 °F (2 to 5 °C) for the year. These are arithmetic averages of the daily maximum and minimum temperature based on or adjusted to the 24 hours ending at 12 mid night. The July maximum temperatures average mostly between 72 and 80 °F (22 and 27 °C), reflecting large diurnal ranges favored by clear, dry summer weather. January average maximums are mostly between 25 and 27 °F (−4 and −3 °C) and are similar on the east and west edges of Glacier Park; the average is down to 22°F (−6 °C) near Marias Pass. The east side may often be much colder than the west in winter, with invading Arctic airmasses blocked by the Continental Divide, but may also be much warmer at times—under chinook wind conditions.

Summer afternoon temperatures are highly correlated with elevation; station data give an overall decrease or "lapse rate" of about 4.3 °F per 1,000 ft (7.8 °C per 1 000 m). The summer nighttime temperatures, however, show the effects of inversions; average minimums on mountain terrain may be higher than those in valleys more than 3,000 ft (900 m) lower. The "mean" temperatures are, thus, also affected. Inversions may persist throughout the day in late autumn and winter. At a 6,000-ft (1 830-m) slope or ridge location, estimated mean temperatures are near 17 °F (−8 °C) in January; 58 (14 °C) in July. On a 9,000-ft (2 745-m) mountain, the estimates are about 8 °F (−13 °C) and 47 °F (8 °C), respectively.

Extreme maximum temperatures during the past 5 years have reached 100 to 105 °F (38 to 40 °C) near the west edge of Glacier Park, slightly lower near the east edge, and 85 °F (29 °C) at 7,500 ft (2 280 m). Minimums have reached between −40 and −55 °F (−40 and −48 °C).

The season between "killing frosts," defined as the period with minimum temperatures above 28 °F (−2°C), averages 4 months (mid- or late May to mid-September) near the east edge of Glacier Park; between 2½ and 3½ months in west-side valley locations. Places such as Polebridge and Summit have minimums down to 32 °F (0 °C) or lower during every month in most years.

Humidity.—Relative humidity, which generally varies inversely with temperature, averages highest near dawn and lowest around midafternoon. The afternoon val-

average highest in midwinter months—averaging about 60 percent near the eastern edge to 75 percent or more in the west and at higher elevations. Averages are down to 35 to 40 percent in July-August at lower elevations; near 45 percent at 6,000 ft (1 830 m). Frequency of a midafternoon humidity below 30 percent, in the west-side valley area, increases from about 23 percent of the days in mid-June to 57 percent in late July and early August; it decreases to 20 percent by late September. A 3-hour change in observation time at fire-weather stations has affected comparability of afternoon humidity (and temperature) data recorded before and after 1974. In addition, during the past 10 years, there has been a regime of higher July-August humidity conditions.

Summer nighttime humidity in the west-side valley area typically recovers to near 90 percent or higher by dawn. On the slopes above the temperature inversions, at the same time, humidity may average only about 60 percent.

Wind.—The seasonal wind patterns show considerable difference across the park. The high, exposed mountain terrain and areas east of the Continental Divide have a pronounced windspeed maximum in winter and a minimum in summer (July-August)—generally following the regime in the free atmosphere. Monthly average (24-hour) speeds may reach about 20 mi/h (32 km/h) on the peaks during November-February; 15 mi/h (24 km/h) near the eastern park edge, where gusts to 100 mi/h (160 km/h) have been reported in chinook episodes. The western valleys tend to have a windspeed minimum in winter, with averages of about 5 mi/h (8 km/h), and a maximum in spring.

During summer, midafternoon windspeeds average about 6 or 7 mi/h (10 or 11 km/h) in the western valley area; 9 or 10 mi/h (14 to 16 km/h) on the east side. Averages at the available lookout stations vary between 6 and 12 mi/h (10 and 20 km/h), influenced by topographic peculiarities. The winds generally decrease at night, with near calm conditions particularly common in the western valleys; however, nighttime increases may often occur on the high mountains.

Prevailing (most frequent) wind directions are from the west or southwest during most of the year. Summer afternoon winds are generally from the southwest, on both sides of the Divide, but some deviations occur due to local topographic channeling. The large-scale wind predominates over local up-valley breezes on the east side. Directions tend to reverse at night on the west side, with local downslope and down-valley air movement dominant.

Sunshine; Solar Radiation.—Late autumn-early winter is normally the cloudiest time of year, with respect to clouds that block out the sun; July-August, the clearest. December sunshine duration averages only about 20 to 35 percent of the maximum possible—or 50 to 90 hours total; this is greatest near the eastern edge of the park. Duration in July reaches about 70 to 75 percent, or 340 to 380 hours, lowest over the mountains and toward the north. Incoming solar radiation (insolation), direct and diffuse, normally totals about 2,500 langleys (gm-cal/cm^2) in December; 19,000 langleys in July; 120,000 langleys for the year. The insolation should generally increase with elevation, but this may be offset by greater cloud cover over the mountains. Effects of slope aspect are greatest in winter. In December and January, a south-facing 30° slope may receive nearly twice as much total radiation as a horizontal surface. In July, the totals should be nearly identical.

Evapotranspiration.—Potential evapotranspiration—integrating effects of temperature, relative humidity, windspeed, and solar radiation—may average about 22 inches (560 mm) at lower elevations during May-October; 26 or 27 inches (675 mm) for the year. These are estimates utilizing adjacent evaporation-pan data. Lesser amounts may be expected at higher, cooler locations. Because of the usual dry period during summer, the actual evapotranspiration will be less than the potential; by perhaps 5 inches (125 mm) or more, for the year, at lower elevations. "Thornthwaite" water-balance diagrams indicate the importance of late spring and July-August precipitation in the severity of a year's soil moisture deficit—and, by implication, the fire season.

Climatic Trends.—Available precipitation records during this century indicate, broadly (by 11-year running means), decreasing annual totals in the Glacier Park area during the 1910's—leading to a long, dry period centered in the 1920's and 1930's; a marked recovery peaking around 1950; and subsequently, little overall change, though there has been a recent downward trend. July-August precipitation, however, increased notably in the 1970's; 11-year and 5-year (weighted) means apparently reached their highest levels of the century. Recent September-October amounts, in contrast, have (until 1984) been exceptionally low.

Temperature data, annual and seasonal, show an overall rising trend during the 1910's and 1920's; a warm period centered in the 1930's or early 1940's (coinciding with low precipitation); a relatively cool period centered around 1950-55; and a lesser rise since then, with some seasonal disparity. Since about 1910, the latest 11-year means indicate a net warming of 1 °F for annual values; 2 °F in both winter and summer.

Some basic climatic statistics for three stations are given in table 18 (appendix).

DETAILS OF THE CLIMATE

Climatic Controls; Broad Weather Patterns

The climate of Waterton-Glacier is governed by a combination of large-scale and small-scale factors. The large-scale factors include latitude, position on the North American continent, prevailing hemispheric wind patterns, and extensive mountain barriers. Small-scale or local factors include the topographic setting and position and the vegetative cover (Schroeder and Buck 1970; Oke 1978). Elevation as a factor has both regional and local components.

Large-scale wind patterns for midwinter and midsummer, at about 10,000 ft (3 000 m) above sea level, are indicated in figure 8. The maps portray average conditions in the "free atmosphere"—above the effects of surface friction and local topography. The inferred

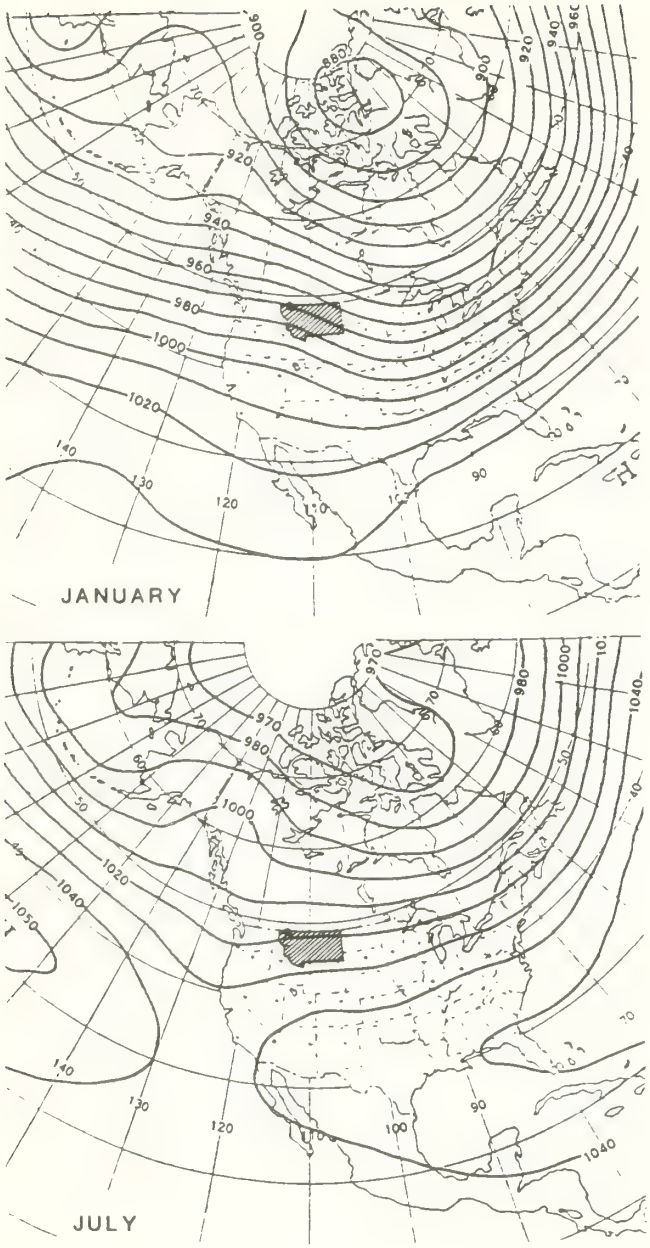


Figure 8.—Average 700-millibar height patterns over North American region for January (A) and July (B): lines are height contours, labeled in tens of feet. Waterton-Glacier location is shown by heavy dot near northwestern corner of Montana (hatched). Maps provided by National Meteorological Center.

airflow—closely parallel to the 700-millibar (mb) height-contour lines—is from a general westerly direction over the Waterton-Glacier location. Corresponding windspeeds are inversely proportional to the spacing between lines. The average wind patterns do, of course, smooth out important day-to-day and year-to-year variations. These variations, through the steering effect of upper-level winds on airmasses and their fronts (Schroeder and Buck 1970; Critchfield 1974), lead to the variety of weather and its anomalies that enter into climatic statistics.

The airflow aloft is generally stronger in winter than in summer; this is related to a greater north-south temperature contrast. The main band of westerly winds retreats northward in summer, and the primary storm tracks are likewise displaced. Large-scale weather systems thus tend to be less active and organized over the United States in summer, though these still often enter the Waterton-Glacier area.

Broadly, the climate of this area is transitional between a northern Pacific coastal type and a continental type (Blair 1942; Hare and Thomas 1974). Superimposed are mountain-climate characteristics. The Pacific influence is noted particularly by a late autumn and winter maximum in cloudiness and precipitation over the park (winter becomes much drier a short distance east); also in the relatively moderate average winter temperatures compared with the continental area farther east—though the averages can be deceiving. Winter temperatures are especially variable on the east side of the park, as arctic airflow alternates with warm downslope winds (chinooks) occurring with Pacific airflow (Cunningham 1982). Summer is generally sunny and dry. July and August, usually the only distinct summer months, are the peak fire-danger months.

Precipitation

ANNUAL PRECIPITATION

Average annual precipitation (fig. 9) is extremely variable across the Waterton-Glacier area. Within the Glacier Park boundary, average amounts (rain plus snowfall water content) range from about 23 inches (585 mm) to 100 inches (2 500 mm) or more. Amounts observed are apt to be somewhat below true values at some of the Montana climatic stations, particularly east of the Continental Divide; this is due to the effect of wind in reducing gauge catch of precipitation, especially snow (Linsley and others 1958). Precipitation averages may be somewhat above true values at some of the Alberta stations, due to a practice of estimating the water content of newly fallen snow from its depth. A fixed ratio of 0.10 is applied, which may often be too high (Landsberg 1958 and present author's experience).

The annual amounts show a strong influence of topographic factors besides elevation. An effect of proximity to the mountains or Continental Divide, favoring heavier amounts, is evident from averages on the east side—for example, 46 inches (1 170 mm) at Many Glacier SNOTEL site compared with 23 inches (585 mm) at the east end of Lake Sherburne. The eastern edge of Glacier Park averages about as much annual precipitation as the western edge, at least from West Glacier northward and East Glacier northward. Amounts do decrease considerably a little farther east at elevations only a few hundred feet lower, with Browning averaging one-half the annual total at East Glacier.

Precipitation increases greatly between the western edge of Glacier Park and Flattop Mountain (fig. 10)—where an 82-inch (2 080-mm) annual average represents a net gain of more than 50 inches (1 270 mm) in an elevational difference of around 3,000 ft (915 m). Precipitation "spillover" across surrounding higher ridges (Huschke

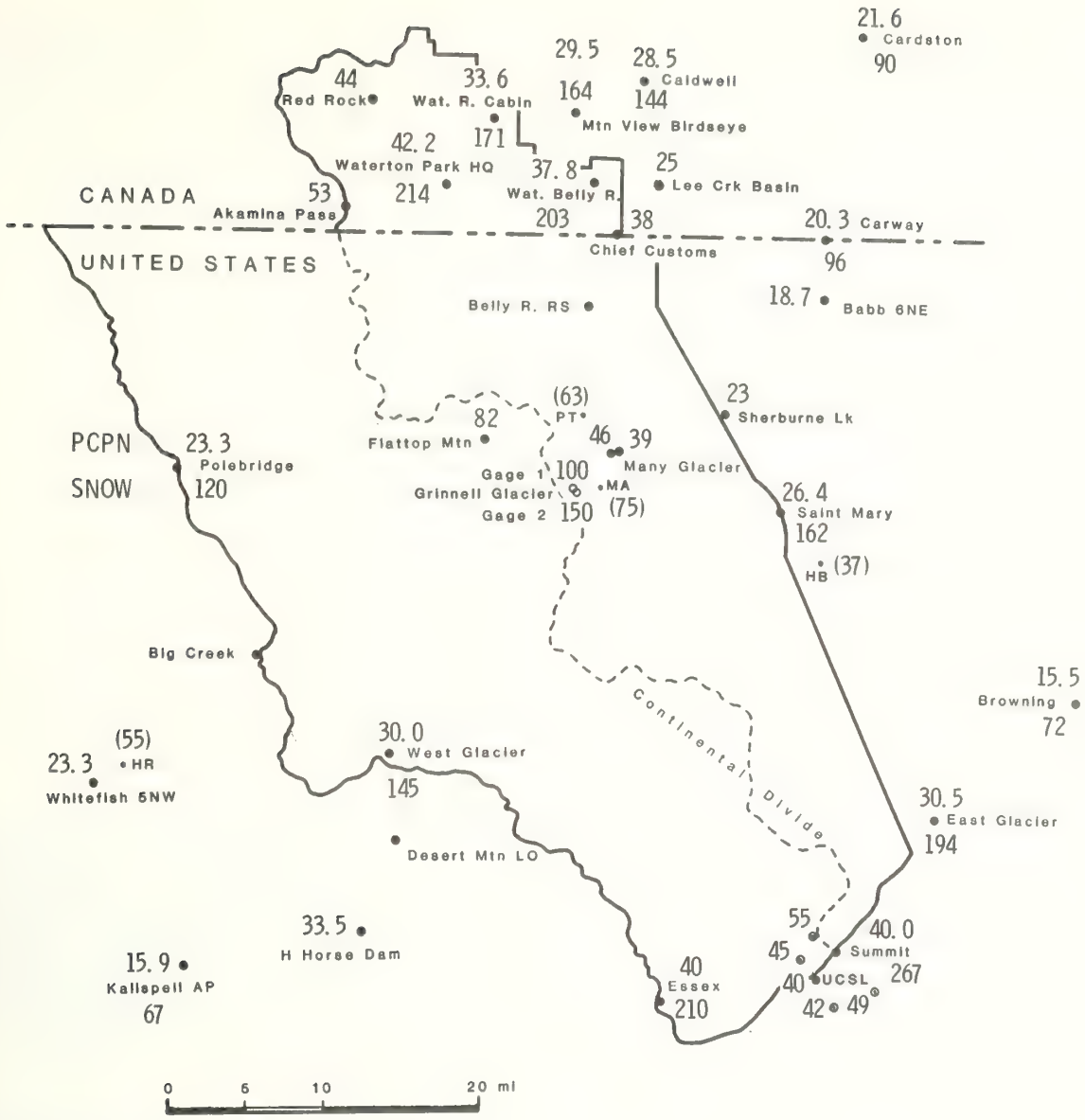


Figure 9.—Average annual precipitation (top or only number) and snowfall, inches, observed in and near Waterton-Glacier Park; based on or adjusted to normal period, 1951-80. Precipitation includes rain and melted snow (snowfall water content generally estimated at Canadian stations; see text). Number in parentheses is annual estimate based on snowpack data.

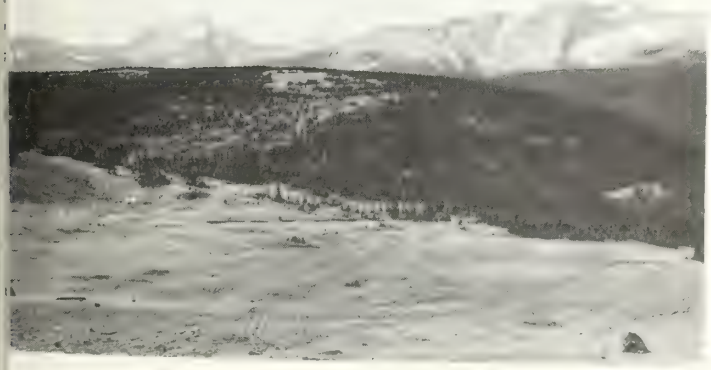


Figure 10.—Flattop Mountain (middle distance), viewed toward southwest, September 1954. Present SNOTEL site, below ridgeline near left edge of photo, averages about 80 inches (2 000 mm) annual precipitation.

1959; Barry 1981) may possibly contribute to this; there is evidently little precipitation shadow effect here. Elsewhere west of the Divide, annual precipitation averages about 40 inches (1 000 mm) at Essex and also at Summit, nearly 1,500 ft (450 m) higher. Near Summit, however, a modest precipitation increase occurs on the former Upper Columbia Snow Laboratory (UCSL) terrain between headquarters and steep ravine locations (stations 10 and 32 in fig. 2) to the east and north—amounts increase 9 to 15 inches (220 to 375 mm) in about 1,500 to 1,800 vertical ft (460 to 540 m). In a study area just north of Waterton Lakes National Park (Poliquin 1973), annual amounts increased about 10 inches per 1,000 ft (250 mm per 300 m).

Extrapolations of precipitation amounts for specific park locations are evidently tenuous, and thus we have not fitted a line pattern to the figure 9 data. (A line pattern, or isohyetal map, is presented for this area by the Soil Conservation Service [1981].) Broadly, the amounts in figure 9 seem to reflect an upslope increase on the usually windward west side and a decrease down the east side; the general physical process is described by Schroeder and Buck (1970). In some storms, the upslope air movement is from the east, reversing the windward and leeward sides. Precipitation enhancement from both the westerly and easterly upslope effects may help explain the exceptionally heavy annual amounts in cirque locations such as Grinnell Glacier (figs. 9 and 11), indicated by two storage-type gauges (fig. 12). (The data are from Dightman 1967b; Johnson 1980; "Storage Gage Precipitation Data for Western United States" annual summaries.)

With the prevailing westerly or southwesterly airflow, precipitation at Grinnell Glacier—at the east face of the Continental Divide's "Garden Wall"—probably includes much spillover from the west side. (Spillover is a result of the precipitation trajectories, affected by the wind.) Also received, both during and after storms, is much previously deposited snow blown off the higher terrain (Matthes 1942; Dyson 1966; Ruhle 1972). Dightman (1956) attests to the occurrence of severe winds, whose damaging effect precluded the use of windshields on the precipitation gauges (to curtail the loss in gauge catch due to wind). The difficulty in obtaining a true catch in this setting may largely account for the 50-inch (1 270-mm) average difference between the two gauges, located only 2,100 ft (640 m) apart and at similar elevations. The 150-inch (3 800-mm) annual average at gauge No. 2 does appear to be excessive (Brown and Peck



Figure 11.—(A) Broad setting of Grinnell Glacier (mostly hidden), toward distant right of center, and portion of Many Glacier area; viewed from northeast, in 1954. Hotel faintly visible on the near shore of Swiftcurrent Lake (middle distance, with Josephine Lake beyond). (B) Closer view of Grinnell Glacier (portion of ice surface visible) and the "Garden Wall," on cool, showery August 31, 1954.



Figure 12.—Storage precipitation gauge (21-ft standpipe) and thermometer shelter near Grinnell Glacier (site No. 1, averaging 100-inch [2 540-mm] annual catch), July 1960.

1962). At gauge No. 1, the gain from blown snow may closely balance out the expected catch deficiency of actual snowfall.

Annual Extremes.—Precipitation totals in individual years can differ by a factor of 2 or more. Amounts at West Glacier since 1931 (table 19, appendix) have ranged from 17.43 inches (443 mm) to 41.38 inches (1 051 mm). Those on record at Summit have ranged from 25.30 inches (643 mm) to 55.39 inches (1 407 mm); at Polebridge, from 13.07 inches (332 mm) to 33.92 inches (862 mm).

MONTHLY DISTRIBUTION

Within most of Glacier Park, December and January normally have the heaviest monthly precipitation (fig. 13). Listed in more detail in table 19 (appendix), January averages range from 3 to 5 inches (75 to 125 mm) at lower elevations to at least 11 inches (280 mm), as at Flattop Mountain. Roughly 45 to 60 percent of the annual total falls during the 5 months November through March, with this percentage generally greatest in the wettest areas.

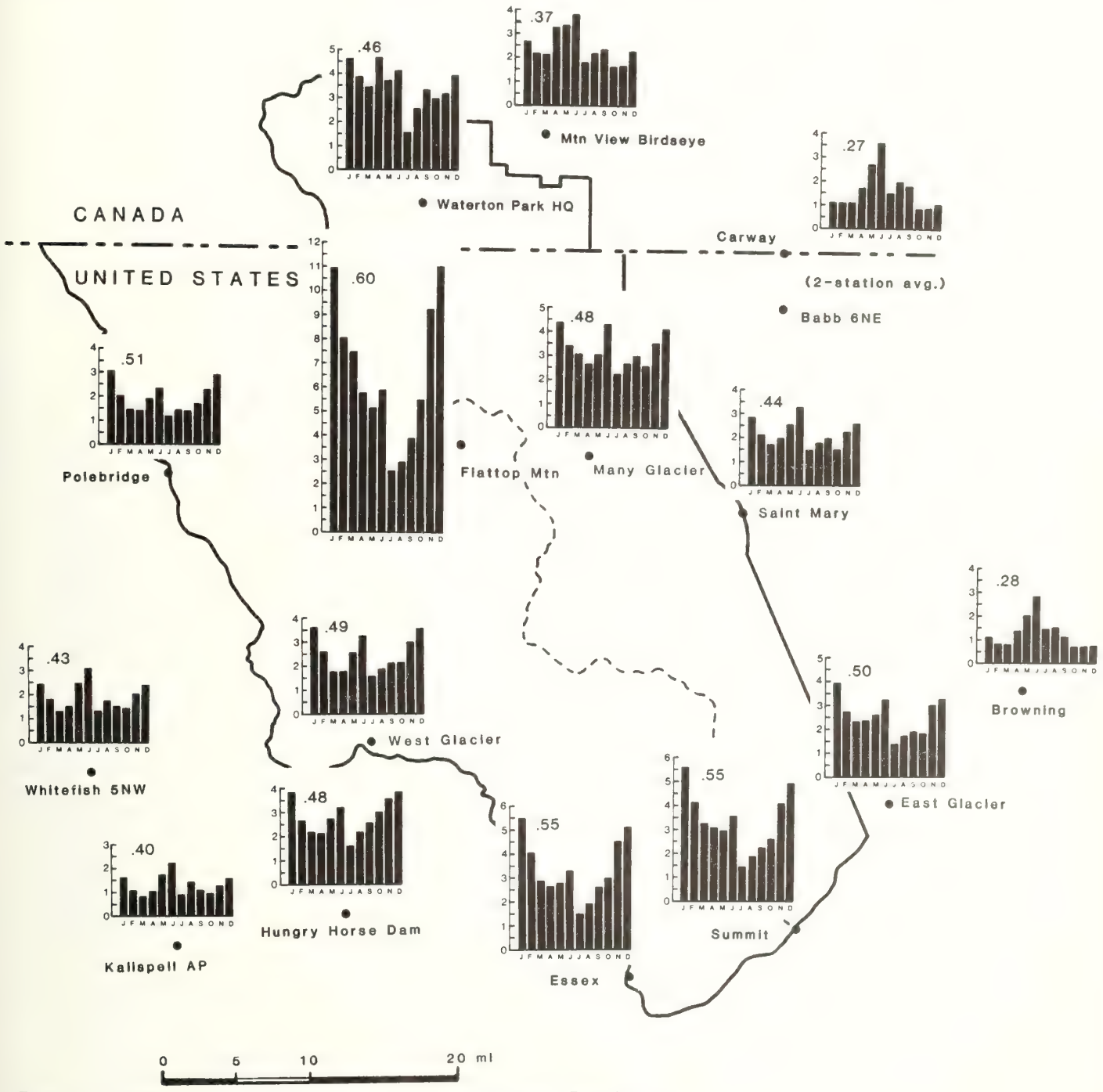


Figure 13.—Average monthly precipitation, inches; annual regime. Based on or adjusted to period 1951-80. Numbers above graphs are ratios of 5-month November-March total to annual total. Amounts shown for Flattop Mountain differ from those in table 19 (Appendix), which are estimated from additional years of data.

Following a decrease during February through early spring, giving March and April averages of about 1.5 to 3 inches (35 to 75 mm) in the valleys, precipitation normally increases in May and June. At many valley locations the June amounts, generally 3 to 4 inches (75 to 100 mm), approach or exceed those of December and January. A large decrease normally occurs in July, the driest month; a rise of a few tenths of an inch in August. Average amounts in summer exhibit relatively small areal difference, shown further in figure 14. July normals are near 1.5 inches (38 mm) on the edges of Glacier Park, though only 1.2 inches (30 mm) at Polebridge; 2.5 to 3.0 inches (63 to 80 mm) on or near some of the higher interior terrain.

The monthly pattern differs somewhat at valley locations in Waterton Lakes Park, where April may be one of the wettest months—averaging about 4.5 inches (115 mm) at Waterton Park townsite. A larger difference occurs in the drier area adjoining Waterton-Glacier. To the east (as at Browning, Babb, and Carway), June is normally the wettest month and May second wettest—the averages, reaching 3 to 3.5 inches (75 to 90 mm) in June, are generally similar to those at lower elevations within the park. December and January both have aver-

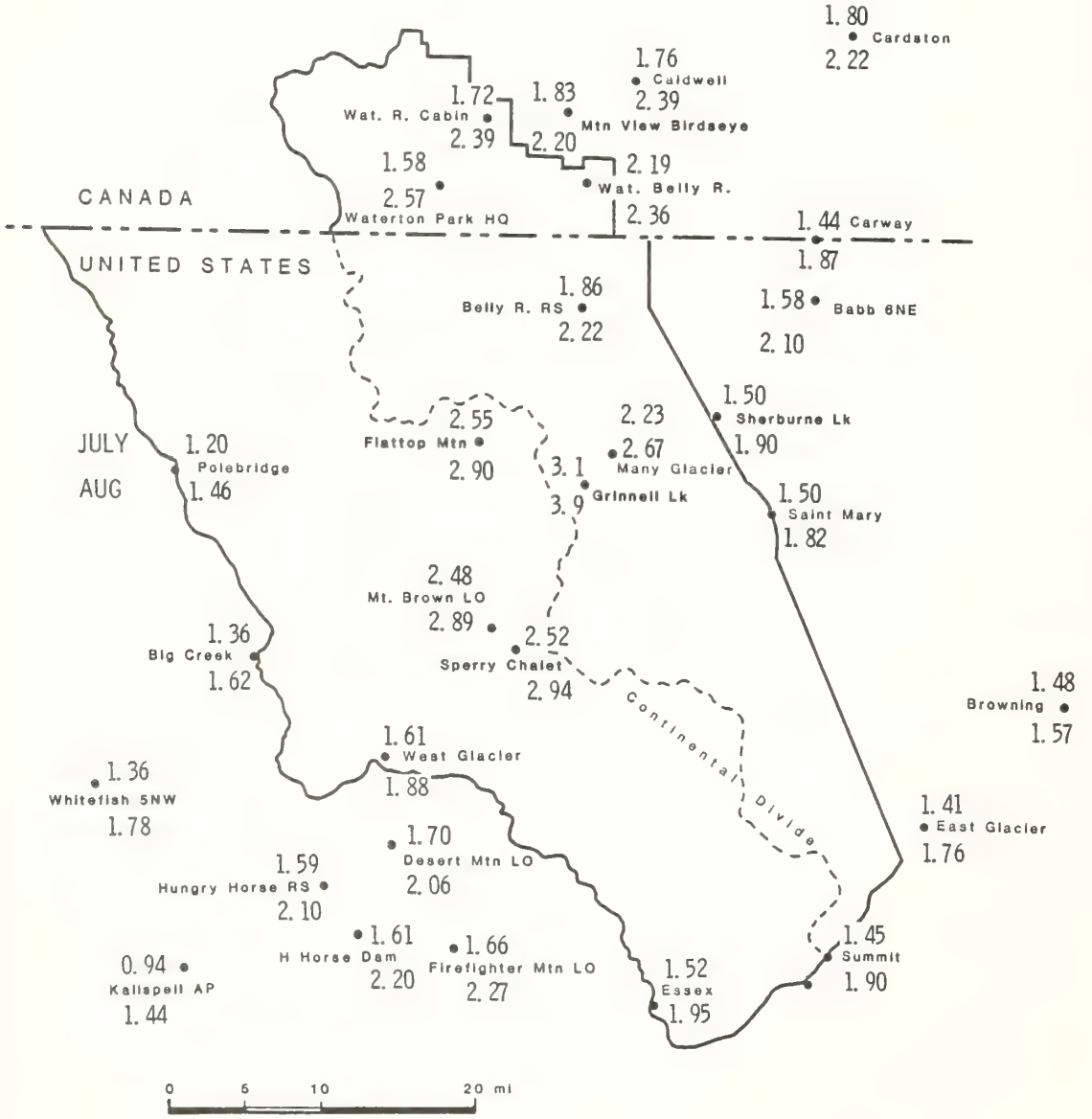


Figure 14.—Average precipitation, inches, during July (top number) and August (bottom number). Based on or adjusted to period 1951-80.

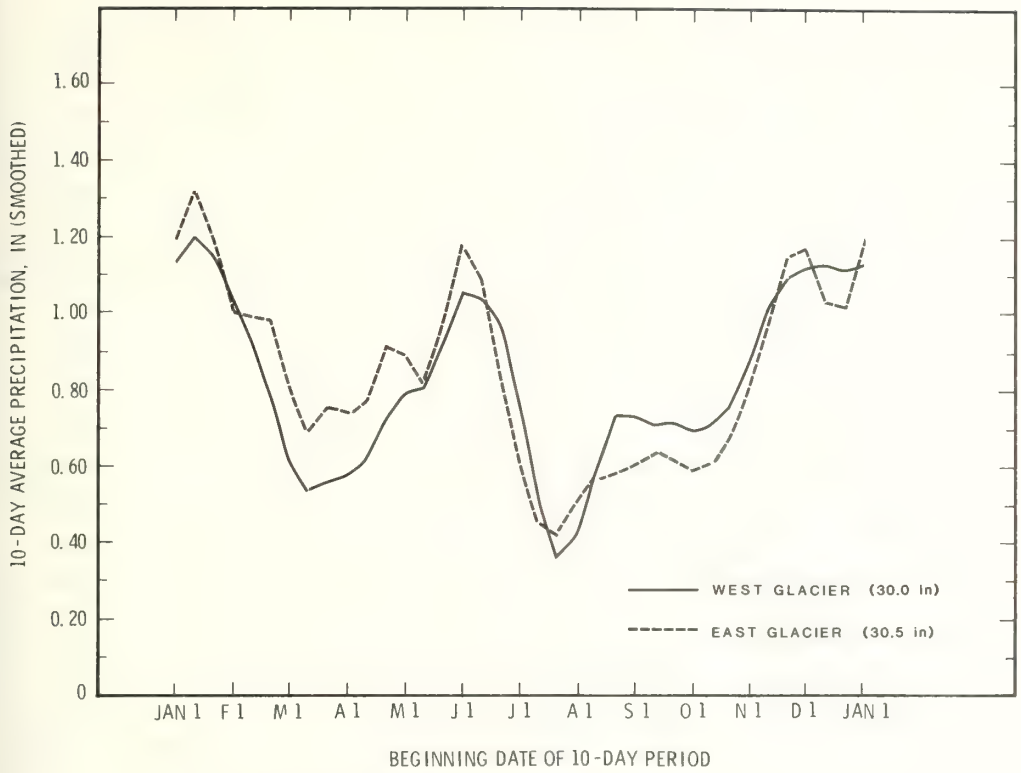


Figure 15.—Comparison of average annual precipitation regime at West Glacier and East Glacier, MT (annual totals shown in parentheses); based on 30 years of data, 1951-80. Lines connect plotted 10-day average values (or averages adjusted to 10-day period), smoothed by a running 1-2-1 weighting factor.

ages of about 1.0 inch (25 mm). Precipitation is more evenly distributed throughout the year in dry Flathead Valley locations such as Kalispell; the May-June total is only slightly higher than that during December-January.

Monthly precipitation amounts for the individual years of record, back to the 1930's, are listed in table 20 (appendix) for Polebridge, Summit, and West Glacier. Ten-day and monthly statistical details are given in table 21 (appendix). A comparison in figure 15 shows an overall similarity of the precipitation regimes at West Glacier and East Glacier, using smoothed 10-day averages. With annual totals nearly identical, East is slightly wetter than West in spring; slightly drier in autumn.

Monthly Extremes.—Monthly precipitation at West Glacier (tables 18 and 21, appendix) has been as high as 7.72 inches (196 mm), observed in December 1980. Totals have reached 6.92 inches (176 mm) at Polebridge and 11.91 inches (303 mm) at East Glacier, both observed in January 1954; 14.00 inches at Summit, in January 1953. Zero or near-zero totals have occurred at all of these stations in July and August. Practically none also occurred in January 1985—0.05 to 0.26 inch (1 to 7 mm).

DAILY AND HOURLY AMOUNTS

Percentage frequencies of various daily precipitation amounts are shown in table 22 (appendix); some of the data are presented in figure 16 (see also table 18, appendix). Generally; the frequencies of relatively small amounts are at a maximum in winter and a minimum in summer. For example, during January amounts of 0.10 inch (2.5 mm) or greater occur on an average of 15 days at Summit, 11 days at West Glacier, and 10 days at Polebridge. The frequency is down to 4 or 5 days in both July and August. This seasonal contrast may change in the case of large daily amounts. At Polebridge and West Glacier, amounts exceeding 0.50 inch (12.5 mm) are equally as frequent (or infrequent) in June as in January—1 or 2 days per month.

Figure 17 portrays the seasonal contrast in frequency of hours with recorded precipitation. During 1948-64 at Summit, the average number of hours with at least 0.01 inch (0.25 mm) ranged from 186 in January to 42 in July; at Polebridge, from 96 to 26. These numbers generally follow the seasonal trends of average monthly precipitation (fig. 13) and numbers of days with precipitation (fig. 16). The frequencies of hourly amounts $\geq$0.05 inch (1.25 mm) exhibit a smaller winter-summer contrast, though at Summit these frequencies follow the secondary precipitation peak in June.

The above data reflect the importance of storm frequency and duration in amassing the heavy winter precipitation; hourly amounts are usually small, less

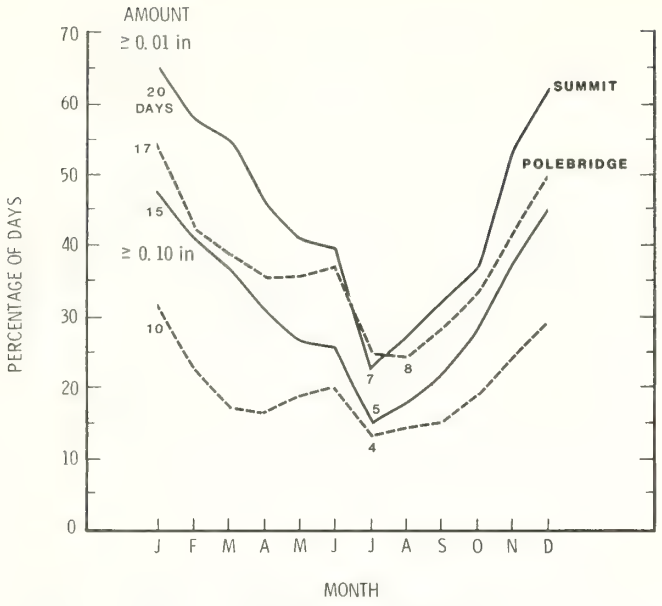


Figure 16.—Monthly percentage of days with precipitation equal to or greater than 0.01 inch (0.25 mm) and 0.10 inch (2.5 mm) at Polebridge and Summit, MT, based on period 1949-78. Plotted numbers are equivalent actual numbers of days, given for extreme months.

than 0.05 inch (1.25 mm). Likewise, the July-August precipitation minimum (fig. 13) is related to fewer days—and hours per day—of precipitation occurrence. Though hourly amounts in summer are more likely to reach higher levels than those in winter, most are still less than 0.05 inch (1.25 mm).

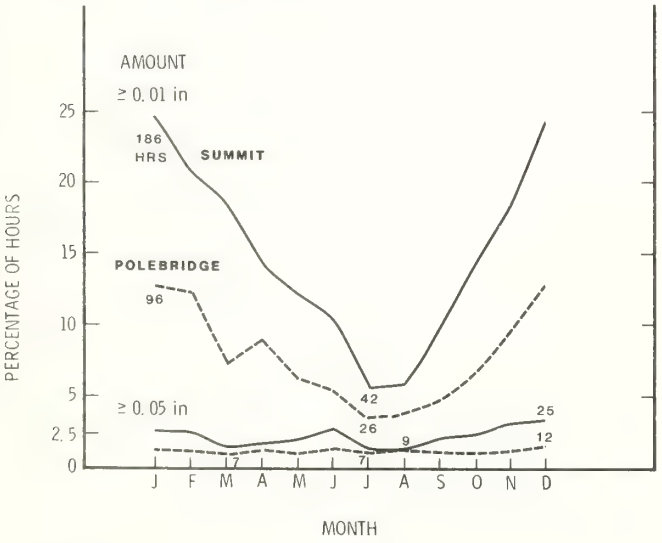


Figure 17.—Monthly percentage of hours with precipitation equal to or greater than 0.01 inch (0.25 mm) and 0.05 inch (1.25 mm) at Polebridge and Summit, MT. Plotted numbers are equivalent actual numbers of hours, given for extreme months. Based on table by Pacific Northwest River Basins Commission (1968) for period 1948-64.

Daily and Hourly Extremes.—Maximum daily precipitation is included in tables 18 and 21 (appendix). Outstanding is the extreme of 7.31 inches (186 mm) at Summit in June 1964—a month notorious for record floods in the Waterton-Glacier area ("Climatological Data," National Summary for June 1964; "Climatological Data," State Summary for Montana, June 1964; Christopherson 1966). This amount, occurring as rain, fell in the 24-hour period ending at 4 p.m. m.s.t., on June 8; the June 7-8 storm total was 8.09 inches (205 mm). The same storm brought a 24-hour record at West Glacier, 3.47 inches (88 mm), but not at Polebridge Also in 24 hours, 6.80 inches (173 mm) fell at East Glacier and 5.90 inches (150 mm) at Browning; about 6.00 inches (150 mm) at Waterton Park Headquarters. Two-day totals at East Glacier and Browning were 8.15 inches (207 mm) and 7.65 inches (194 mm), respectively. An estimated 12 inches (300 mm) fell on some of the high east-side slopes—still covered with exceptionally heavy snowpack.

During this storm, the expected 100-year, 24-hour extreme amounts shown by Miller, Frederick, and Tracy (1973) were equaled at West Glacier and exceeded by 2 to 3 inches (50 to 80 mm) at the more eastern stations.

Maximum 1-hour amounts, available for Summit, are listed in table 1. No exceptional, "cloudburst" values ar noted. The 35-year extreme, 0.54 inch (14 mm) during the June 1964 storm, is about one-half the calculated 100-year and 25-year extremes (above reference). A total of 2.92 inches (74 mm) accumulated in a 6-hour period o this storm, well above the 100-year value shown as 2.2 inches (56 mm). In the cooler months of the year, highest recorded 1-hour amounts at Summit are mostly about 0.20 inch (5 mm).

Less complete data or shorter records from Polebridge West Glacier, and Browning show similar 1-hour extremes of about 0.60 inch (15 mm), observed in different years. Much heavier downpours can occur locally, however, even in drier locations—as was the case when 2.57 inches (65 mm) fell at the Kalispell airport in 1 hou (between 6 and 7 p.m.) on June 29, 1982.

PRECIPITATION DURING FIRE SEASON

Some precipitation details, by 10-day periods, are plot ted in figure 18; these, taken from tables 21 and 22 (appendix), cover the official fire season (May-October) and 1 or 2 months before and after. Details for additional fire-weather stations are given in tables 23 and 2 (appendix). Figure 18 shows that precipitation is normally lowest between July 10 and August 20, sandwiched between the springtime peak during June and a pronounced increase in late August. The 10-day averag do not indicate much further increase until November. The corresponding frequencies of various daily amounts (and 10-day totals) follow a similar pattern. A high corr lation between frequencies and averages is indicated fu ther in figure 19. Given the 10-day average precipitatio this graph may be used to estimate the climatic probability of a day with "wetting" precipitation, 0.10 inch (2.5 mm) or more, during any portion of the fire season at various Glacier Park locations.

Table 1.—Monthly maximum 1-hour precipitation, inches, at Summit, MT, during period 1948-82[1]

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
No. years[2]	25	29	24	28	30	30	34	32	31	30	26	22	
Average	0.14	0.12	0.11	0.12	0.17	0.23	0.19	0.20	0.16	0.14	0.14	0.12	
Extreme,[3]	0.40	0.22	0.2	0.2	0.30	0.54	0.4	0.5	0.33	0.3	0.20	0.20	0.54
year	1953	1951	1974, 1982	1977, 1979	1953	1964	1975	1976	1952	1980	1955	1955	1964 June

[1]Data from weighing-type recording gauge through January 1973; from Fischer-Porter gauge, with only 0.1-inch increments, beginning February 1973.
[2]Years with complete data (or noncritical missing data).
[3]Given to tenths of an inch when value is that from Fischer-Porter gauge.

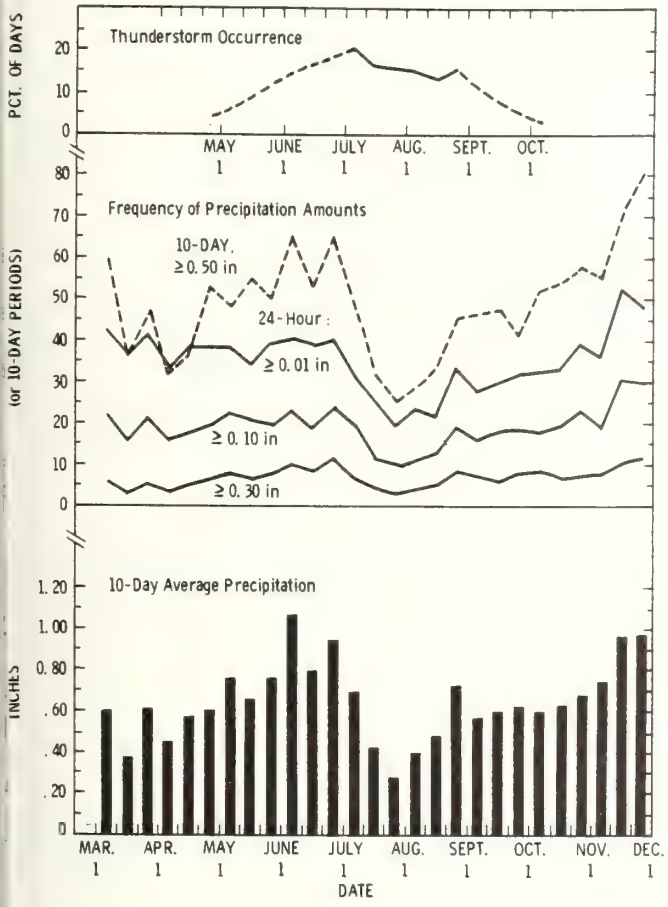


Figure 18.—Ten-day precipitation and thunderstorm occurrence, near west edge of Glacier Park; values plotted at middle of periods. Precipitation is two-station average from Polebridge and West Glacier, 1951-80. Amounts for 11-day periods are adjusted to 10 days. Thunderstorm graph for July and August is based on Desert Mountain Lookout, 1936-71 (storms within about a 10-mile radius); for other months (dashed line), occurrence is approximated from Ranger station and Kalispell airport data.

Although July and August are normally dry, many exceptions do occur. Notable in table 20 (appendix) are the consecutive summers of 1975-78. Combined July-

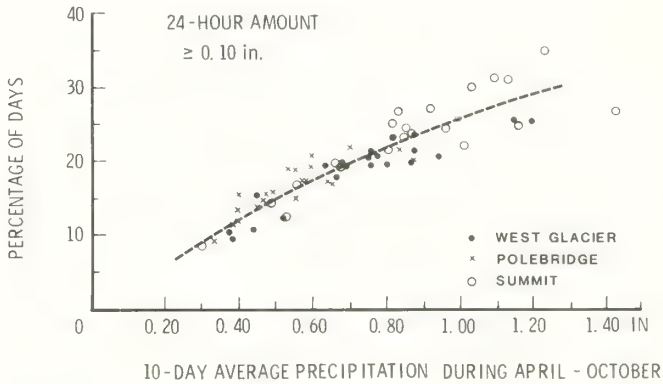


Figure 19.—Relationship between frequency of days with precipitation ≥ 0.10 inch (2.5 mm) and the 10- (or 11-) day average precipitation, April-October. Based on 30 years 1949-78 at indicated stations. Dashed curve fitted by eye.

August precipitation in 1978 totaled 6.06 inches (154 mm) at Polebridge and 7.52 inches (191 mm) at West Glacier. These stations had still larger amounts of 6.77 inches (172 mm) and 8.29 inches (211 mm), respectively, in July-August 1954.

SNOWFALL

Annual and Monthly Snowfall.—Average annual snowfall totals are included in figure 9; monthly totals, in table 19 (appendix). These represent the sums of individual daily snowfall accumulations, ideally measured before any reduction—by settling, melting, or wind action—occurs. Along the edges of Glacier Park (and at lower elevations of Waterton), the 30-year annual averages range from 120 inches (305 cm) at Polebridge to 267 inches (678 cm) at Summit. During January, generally the snowiest month, these two stations have averages of 35 inches (90 cm) and 56 inches (143 cm), respectively. (April is normally the snowiest month at the Waterton Lakes Belly River station.) In the higher reaches of the park, annual totals may average as much as 800 to 1,000 inches (2 000 to 2 500 cm) (communication from Phillip E. Farnes). A location with 80 inches (2 000 mm) precipitation, such as Flattop Mountain, may receive snowfall of 650 inches (1 650 cm) or more. The maximum depth attained by the snowpack will, of course, be considerably less.

Figure 20 indicates that snowfall water content contributes 50 percent of the annual precipitation at a park elevation of about 4,500 ft (1 370 m). The 70 percent level may be near 6,500 ft (1 980 m). The snowfall proportion is lower on the plains to the east, a result of the smaller proportion of wintertime precipitation. Individual monthly and annual (seasonal) snowfall totals are listed in table 25 (appendix).

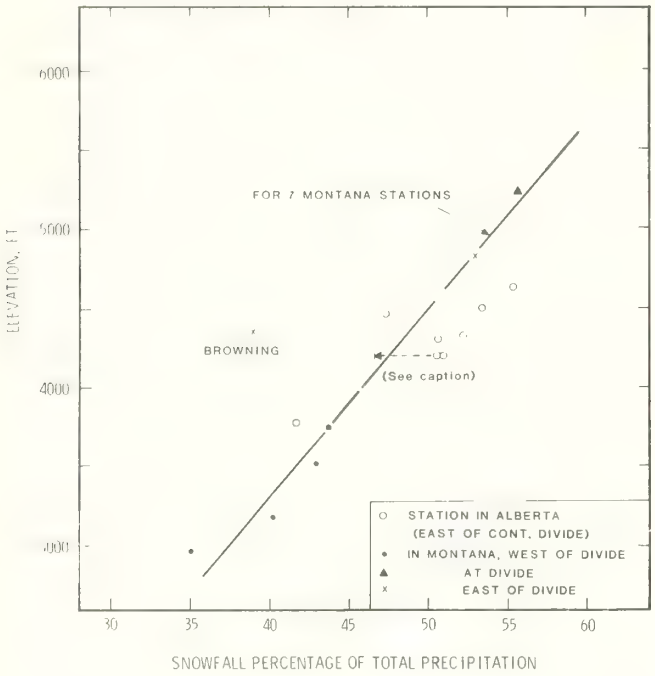


Figure 20.—Percentage of annual precipitation occuring as snowfall, in relation to elevation, at stations in or near Waterton-Glacier Park, based on or adjusted to period 1951-80. Regression line is based on the Montana stations, excluding Browning; assumes an overall 12 to 1 snowfall/water-content ratio. Percentage values at Alberta stations use published precipitation estimates assuming a 10 to 1 ratio; arrow at end of dashed line illustrates result if 12 to 1 ratio is used.

Extreme Seasonal and Monthly Snowfall.—Seasonal snowfall at West Glacier has varied from 46 inches (117 cm) to 279 inches (709 cm), observed in 1971-72; at Summit, from 143 inches (363 cm) to about 392 inches (996 cm), including estimates for some incomplete 1971-72 data. This particular season brought 215 inches (546 cm) at Polebridge and 321 inches (815 cm) at East Glacier. Highest recorded monthly totals at these four stations range from 91 inches (232 cm) at Polebridge in January 1954 to 131 inches (333 cm) at Summit in January 1972. In contrast, January 1985 brought only 1 to 4 inches (3 to 10 cm).

Daily Snowfall.—At higher elevations, snowfall of at least 1.0 inch (2.5 cm) may occur on an average of 40 percent or more of the days during November through March. Summit has an annual average of 76 snowfall days (table 18, appendix), with 15 of these in January and 14 in December—though rain may also fall here during winter. West Glacier has nearly as many snowfall days in December-January but just 44 days annually. This number decreases to 37 days at Polebridge. Frequencies of various daily snowfall amounts are shown in table 26 (appendix).

An extreme 1-day snowfall of 44 inches (112 cm) was measured at Summit in January 1972, with a 2-day total of 54 inches (138 cm); 35 inches (89 cm) at East Glacier in December 1971, with a 2-day total of 39.5 inches (100 cm). Polebridge and West Glacier have received 20 inches (51 cm) in 1 day; Waterton Park Headquarters, 2 inches (74 cm) (in November).

Summer Snowfall.—Snowfall may sometimes occur in July or August at the higher elevations, though still somewhat uncommon at 7,500 ft (2 280 m). Mount Brown Lookout, at this level, had such snow accumulation in at least 5 of the years during 1930-57, mostly in late August; 9 inches (23 cm) in August 1932 and 1947. Sperry Chalet, at 6,575 ft (2 000 m), during 1960-75, h 4 years with late August snowfall; 4 inches (10 cm) in 1960. More unusual, Summit, at 5,215 ft (1 590 m), received 4 inches (10 cm) in mid-July 1972.

Snow Depth; Snowpack.—At locations along the edg of Glacier Park, snow cover (depth of 1 inch or more) i usually continuous from sometime in November to son time in April or May (fig. 21, upper panel). Average duration of continuous cover ranges from 134 days at West Glacier to 194 days at Summit. The average dep peaks in February at Polebridge and West Glacier, at near 2 ft (60 cm); in March at Summit, near 4.5 ft (140 cm) (fig. 21, lower panel). Seasonal maximum dep which may occur at other times, averages somewhat greater (table 2). Extreme depths have reached 54 to 58 inches (137 to 147 cm) at Polebridge and West Glacier; 132 inches (335 cm) at Summit.

The average snowpack density at Marias Pass is shown in figure 21, lower panel, to increase from 0.25 i January 1 to 0.35 on April 1 and 0.40 on May 1. Dat from this and other snow courses are summarized in table 27 (appendix). Only a May 1 snow survey is tak at some of the courses in the Many Glacier vicinity; snowpack at those courses above 5,500 ft (1 700 m) is near a seasonal maximum at this time of year.

The Mount Allen course has a normal May 1 snow depth of 9 ft (2.7 m), with a water content of 48 inche (1 222 mm). Flattop Mountain has about 53 inches (1 350 mm) water content on May 1 and still averages 43 inches (1 100 mm) on June 1; the snow often rema here into July.

THUNDERSTORMS

The main season of lightning (or thunderstorm) activity extends from about mid-May to mid-Septem Figure 18 (top panel) shows that storms within a giv 20-mile (32-km) observing radius may occur on 15 to percent of the days during June, July, and August—an average of 5 days per month. (The frequency of a storm occurring anywhere within the entire Waterto Glacier area will be somewhat greater.) The higher, r centrally located Mount Brown Lookout reported an average of 7 to 8 storm days in July and 6 days in

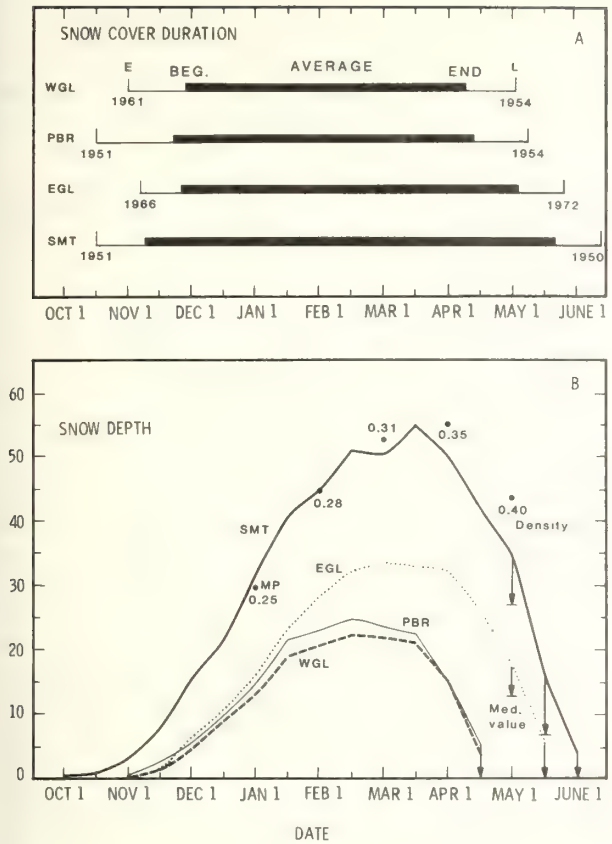


Figure 21.—Snow cover and snow depth observed at edges of Glacier Park; at Polebridge (PBR), West Glacier (WGL), Summit (SMT), and East Glacier (EGL). Panel A: Average duration (heavy bar), earliest beginning date (E), and latest ending date (L) of continuous seasonal snow cover ≥ 1 inch; calendar years shown for extreme dates. Averages generally based on period 1951-80; extremes, 1949-83; EGL data, 1965-83. Panel B: Average seasonal depths based on values at middle and end of months; years as above, except 1949-68 at SMT. Heavy dots denote 1951-80 average at Marias Pass (MP) snow-survey course near SMT; plotted numbers, snowpack density (water-content/snow-depth ratio). Heads of arrows, plotted in late season, indicate median values of snow depth.

ble 2.—Monthly and seasonal maximum snow depth,[1] inches: average (avg.), median (med.), and record highest and lowest—based on indicated water years; calendar years shown for extreme values. M denotes value missing

ation		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Annual
st Glacier	Avg.	2	4	12	23	32	37	39	34	16	0	44
965-85	Med.	0	3	10	20	30	40	40	32	11	0	47
	High,	10	24	35	54	79	81	83	59	55	M	83
	yr	1984	1984	1978	1964	1972	1972	1972	1971	1967	1965	1972
	Low,	0	0	1	4	6	5	7	2	0	0	15
	yr											1972
olebridge	Avg.	0	2	9	18	28	30	27	16	1	0	34
951-80[2]	Med.	0	0	7	18	28	33	28	16	0	0	36
	High,	5	11	22	39	54	47	50	51	14	M[5]	54
	yr	1949	1984[4]	1959	1951	1954	1949	1954	1954	1954	1966	1954
	Low,	0	0	1	6	8	3	4	0	0	0	10
	yr											1977
ummit	Avg.	3	7	20	37	51	59	61	57	36	3	69
949-68[3]	Med.	0	6	20	34	48	57	60	54	27	0	72
	High,	18	37	49	54	105	84	96	132	86	23	132
	yr	1965	1951	1959	1957	1954	1954	1954	1954	1954	1950	1954
	Low,	0	0	6	20	30	11	25	21	0	0	30
	yr											1977
est Glacier	Avg.	0	1	8	16	26	29	25	16	1	0	31
951-80[2]	Med.	0	0	6	15	26	28	26	17	0	0	32
	High,	1	8	27	40	58	55	49	44	8	M[5]	58
	yr	1972	1984[4]	1959	1984	1972	1972	1972	1954	1954	1966	1954
	Low,	0	0	1	6	9	11	5	0	0	0	14
	yr											1961

[1]At daily (generally afternoon) observation time.
[2]High and low for period 1949-85.
[3]Low and all Sept., Oct., Nov., and June data for period 1949-79. Other data not included beyond 1968 due to suspected highly excessive lues.
[4]Also in 1951.
[5]Possibly several inches.

August (1931-57 data). Coram Ranger Station (R.S.) and Hungry Horse R.S. combined, Polebridge R.S., and Belly River R.S. all reported an average of 4 storm days per month in July and August (1946-70 data).

The ranger station data may omit some of the thunderstorms, due to the more limited view and hours of vigil. The above numbers, nevertheless, suggest a similar frequency of storms on the west and east sides of Glacier Park and an increase over higher, rugged terrain. This would be in line with averages from the adjacent primary National Weather Service stations and derivative map portrayals of annual occurrence (Baldwin 1973; Bryson and Hare 1974). For the Glacier Park area, these maps indicate about 25 to 30 thunderstorm days per year around a given location.

Data from Desert Mountain and Mount Brown (table 3) show a pronounced afternoon and early evening maximum in thunderstorm activity. About 50 percent of the defined July and August storms began during the 6 hours between 1200 and 1800 m.s.t. Only 7 to 9 percent began between 0300 and 0900.

Table 3.—Frequency distribution of beginning times of thunderstorm activity, July and August; by 3-hour periods. Storms within about a 20-mile (32-km) radius, in or near Glacier National Park, observed at Desert Mountain Lookout (1936-71) and Mount Brown Lookout (1931-57)

Beginning time, m.s.t.	Lookout, number of storm cases[1]	
	Desert 360	Brown 213
	Percent of total	
0000-0259	6.9	5.6
0300-0559	4.7	4.7
0600-0859	4.4	2.3
0900-1159	7.2	4.2
1200-1459	21.7	24.4
1500-1759	24.4	28.2
1800-2059	19.2	22.5
2100-2359	11.9	8.0

[1]On days with recurrent storm activity, individual storm periods are arbitrarily defined by at least 3 hours interval between observed lightning.

Detailed lightning observations at Desert Mountain during July-August 1960-71 indicate a Lightning Activity Level (LAL) (Deeming and others 1977) of 5 in 20 percent of the 81 usable storm cases, or on 3 percent of all days. This is based on 15-minute counts of cloud-to-ground lightning (Project Skyfire data, filed at Intermountain Fire Sciences Laboratory). The LAL was 2 in 51 percent of the cases, 3 in 17 percent, and 4 in 12 percent. These values are similar to those from Gisborne Lookout in northern Idaho (Finklin 1983b).

Temperature

ANNUAL PATTERN; MONTHLY AVERAGES

Temperatures described here are those of the air measured generally about 5 ft (1.5 m) above the ground. The yearly course of average maximum and minimum temperatures is portrayed in figure 22—for both lower and higher elevations on the west side of Glacier Park. The 6,000-ft (1 830-m) slope location curves are based primarily on data from the Coram "clearcut" station (CCUT in fig. 2)—on an east slope at 5,200 ft (1 585 m)—and the UCSL "station 10"—up a west-facing ravine at 6,340 ft (1 933 m). (See "Stations; Data; Methods" section.)

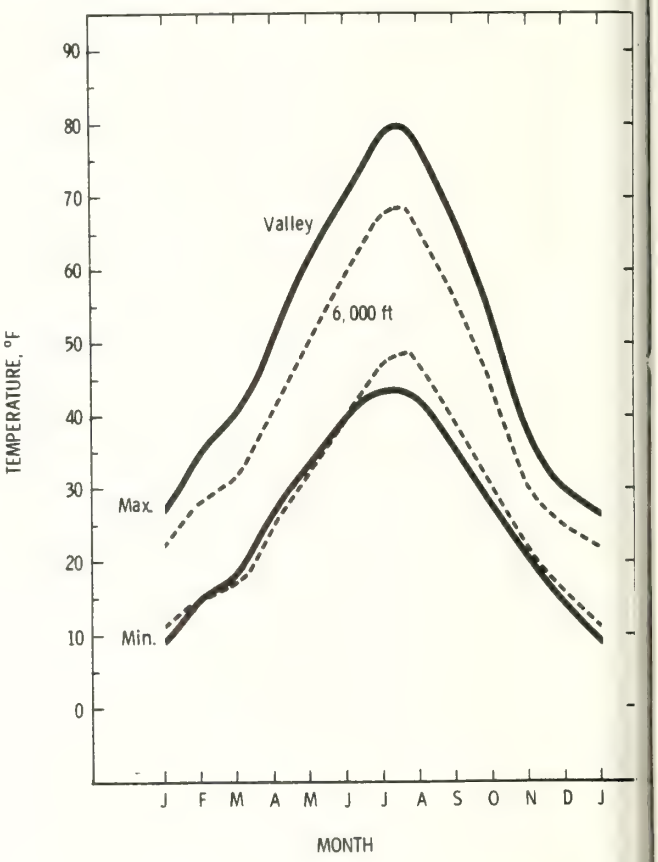


Figure 22.—Average daily maximum and minimum temperatures; annual regime. Based on or adjusted to period 1951-80 and midnight-midnight observation day. For west-side valley area of Glacier Park—based on a Polebridge-West Glacier average—and a 6,000-ft (1 830-m) slope location (see text).

The pattern in figure 22 should apply to other Waterton-Glacier locations, even though actual temperatures will vary. This is shown by the averages listed in table 28 (appendix), which also indicate influences of local factors besides elevation. January is normally the coldest month; July, the warmest. The available averages for these two months are mapped in figures 23 and 24.

January average maximum temperatures are about 2 to 27 °F (−4 to −3 °C) in the valley areas on both side of the park; 22 °F (−6 °C) near Marias Pass. July average maximums are as high as 80 °F (27 °C) in the west side valleys; generally 75 °F (24 °C) or lower on the east side. Diurnal ranges between average maximum and minimum temperatures increase in summer, reaching 3 to 40 °F (19 to 22 °C) in west-side valley areas. On the mountains and slopes, however, these ranges reach only about 20 °F (11 °C).

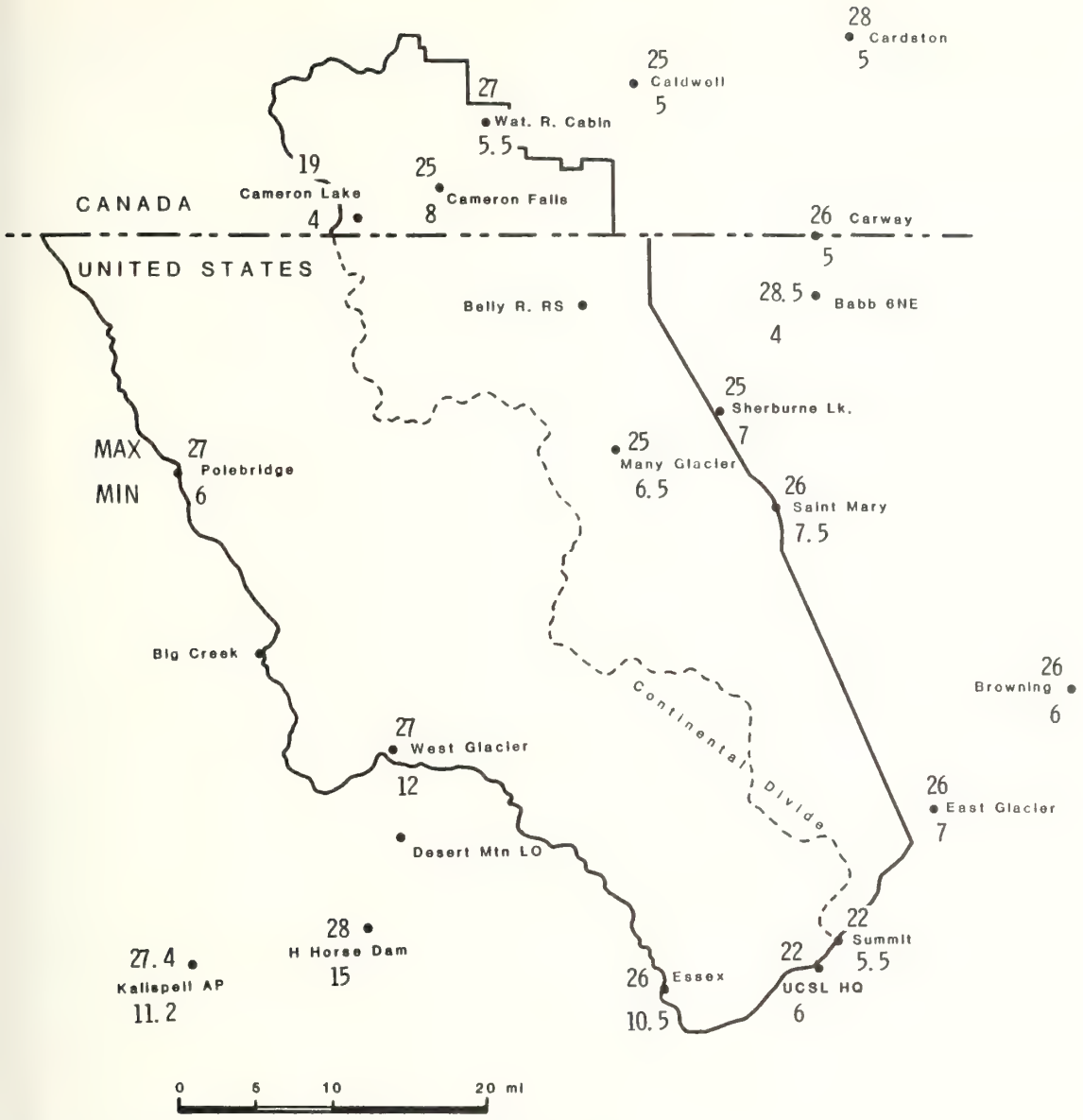


Figure 23.—Average daily maximum and minimum temperatures, °F, during January. Based on or adjusted to period 1951-80 and midnight-midnight observation day (the actual calendar day).

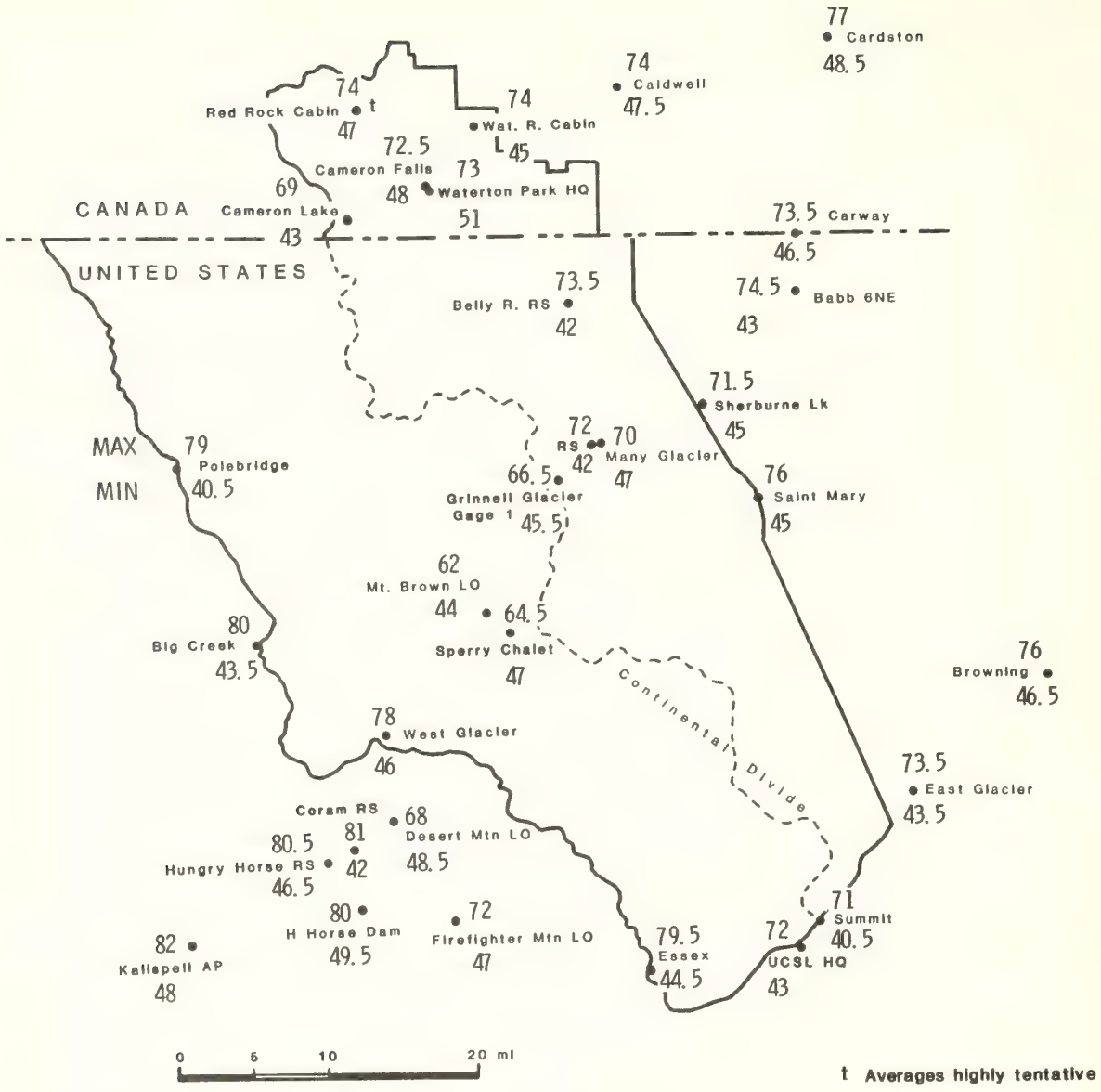


Figure 24.—Average daily maximum and minimum temperatures, °F, during July; as in figure 23. Averages at Grinnell Glacier (observed near picnic area) are estimated from August data.

Average maximum and minimum temperatures for each month of record, back to the 1930's, are listed in table 29 (appendix). Ten-day and monthly statistical details are given in table 30 (appendix); frequencies of various temperatures, in table 31 (appendix).

Smoothing out some of the local daytime and nighttime effects are monthly "mean" temperatures—calculated as arithmetic averages of the maximum and minimum temperatures. These values, shown in table 32 (appendix), give a good approximation of actual 24-hour averages. Normal January means in the valley or canyon areas below 5,000 ft (1 525 m) are generally between 15 and 20 °F (−10 and −7 °C), based on or adjusted to the calendar day. Corresponding July means vary from about 57 to 62 °F (14 to 17 °C); annual means, 36 to 41 °F (2 to 5 °C). Monthly mean temperatures at 6,000 ft (1 830 m) may be near 17 °F (−8 °C) in January and 58 °F (14 °C) in July. On a 9,000-ft (2 745-m) mountain, the estimates are about 8 °F (−13 °C) and 47 °F (8 °C), respectively.

Inversions; Temperature Variability.—Effects of nighttime temperature inversions are evident in figures 22 and 24. Nighttime inversions, favored by clear, calm weather conditions (Schroeder and Buck 1970; MacHattie 1970) are most frequent during July through early autumn. Minimum temperatures during this time average higher at lookout locations than at valley stations over 3,000 ft (915 m) lower in elevation. A "thermal belt" (Hayes 1941; Geiger 1965), with highest nighttime and 24-hour average temperatures, may be expected on the intervening slopes—at or near the typical inversion top. Such a belt is indicated in the Coram Experimental Forest, as shown later.

Temperature inversions in late autumn and winter

ften persist throughout the daylight hours, particularly the west-side valleys. Such inversions may be ssociated with a warmer airmass aloft (overriding a allow or remnant cold airmass), in addition to night-me surface cooling. They are indicated on a local scale y averages from the Coram and UCSL stations, resented later. On a larger scale, these inversions would elp explain the east-side and west-side similarity in anuary average maximum temperatures (fig. 23) despite e elevational difference (fig. 2).

The east side, however, experiences greater year-to-ear (and probably day-to-day) variation in winter tem-eratures, with contrasting Arctic airmass and chinook nditions. This is indicated by the standard deviations reese 1967; Snedecor 1956), plotted in figure 25. Over 30-year period, January maximum temperatures here ay average more than 8 °F (4.5 °C) above or below rmal in 10 of the years; in the west-side valleys, 5 °F °C) above or below normal.

Relatively small year-to-year variation in average aximum temperature is indicated in late spring and rly summer on both sides of Glacier, but this increases August and September. Notable in figure 25 is the en smaller variability of average minimum tempera-res around this time of year at the valley-type loca-ns; standard deviations for 4 months are near 2.0 °F .0 °C). Apparently contributing to this are the rela-vely cool nighttime temperatures that may occur under e same (clear, dry) conditions associated with warmest ytime regimes. This behavior was shown for the lway-Bitterroot Wilderness in Idaho (Finklin 1981).

Table 4 illustrates the poor correlation between a val-y station's average maximum and minimum tempera-res during summer months; the coefficient r, in fact, s a negative value at Polebridge. High correlations are und during the cloudy winter months, with r around 95 in January.

Relationship to Elevation; Horizontal Gradients.—gure 26 shows July average maximum temperatures tted against elevation. The best-fit line, or linear gression (Freese 1967; Snedecor 1956), gives an overall nperature decrease, or "lapse rate," of 4.3 °F per 00 ft (7.8 °C per 1 000 m). This is similar to the rate tained in the lower free atmosphere, several hours er, at adjacent "radiosonde" (upper-air sounding) sta-ns (table 5). Though the correlation with elevation is h (r equal to −0.97), the average maximum tempera-e at a particular location can differ by 2 °F (1 °C) or more from the regression estimate. Such variation is also shown by data from MacHattie (1970), as illustrated later.

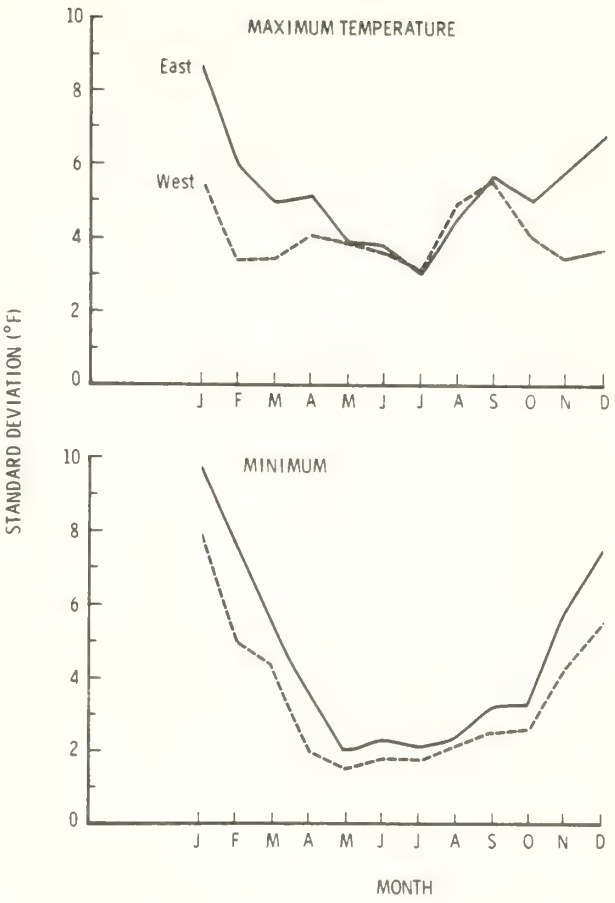


Figure 25.—Standard deviation (SD) of monthly average daily maximum and minimum temperatures, at valley stations in or near Glacier Park. Based on 30 years, 1949-78. West denotes Polebridge-West Glacier average SD; east, Babb 6NE-Browning average.

Figure 26 also includes point values and regression lines for the July mean temperatures. Affected by the nighttime inversions, it is evident that the means must be treated separately for the valley and mountain locations. Within these two groupings—but not between them—the resulting lapse rates average about 3.3 °F per

ble 4.—Correlation between average daily maximum and minimum temperatures at individual stations, for selected months (listed in seasonal order); based on period 1949-80

tion	No. years	Dec.	Jan.	Feb.	May	June	July	Aug.	Sept.	Oct.
		Correlation coefficient, r								
bb 6NE	32	0.92	0.96	0.92	0.48	0.80	0.30	0.34	0.63	0.74
wning	31	.96	.96	.91	.58	.72	.46	.54	.76	.74
ispell AP	32	.93	.96	.85	.62	.58	.14	.10	.47	−.24
lebridge	32	.83	.94	.78	.47	.28	−.15	−.19	.13	−.35
nmit	27-31	.92	.96	.82	.29	.75	.05	.09	.67	.64
st Glacier	32	.93	.97	.86	.52	.59	.10	.15	.52	−.02

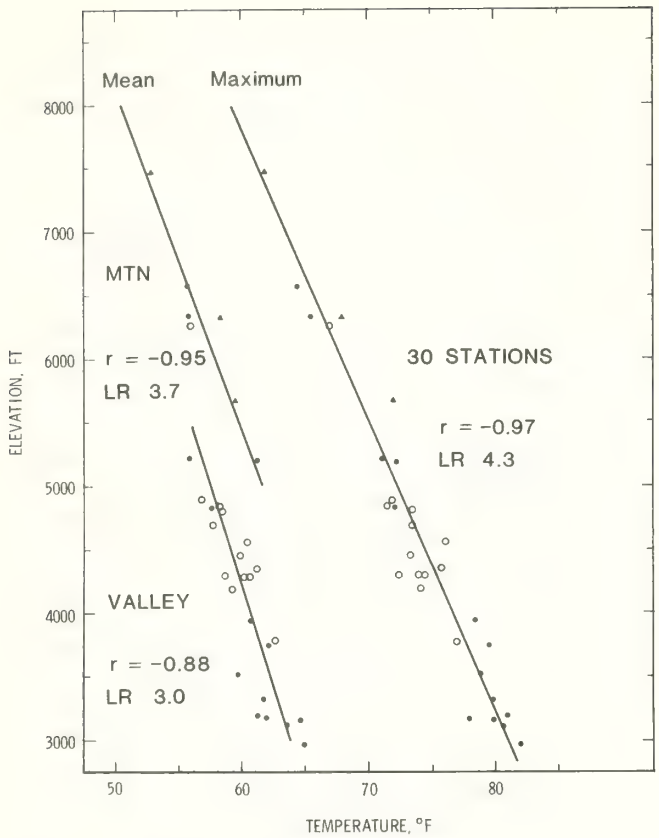


Figure 26.—Relationship between average temperature and elevation, July; Waterton-Glacier Park and vicinity. Data from 30 stations; based on or adjusted to the period 1951-80 and actual calendar day. Dots denote stations west of Continental Divide (triangles, lookouts); open circles, stations east of Divide. Fitted lines are based on regression equations—calculated for average daily maximum temperature and for mean temperature (arithmetic average of maximum and minimum). LR is slope of line converted to °F per 1,000 ft.

1,000 ft (6.0 °C per 1 000 m), somewhat less than the mean rate derived from table 5. Smaller wintertime laps rates suggested earlier are also indicated in this table.

Horizontal temperature gradients in the free atmosphere are indicated in figure 27. The average isotherms near 10,000 ft (3 000 m) run closely parallel to the wind flow (fig. 8). The gradient over the Northern Rocky Mountain area appears stronger in summer than in winter—contrary to generalizations made for North America as a whole. Across Glacier Park, related horizontal differences in temperature may average up t 0.7 °F (0.4 °C) in January and up to 1.5 °F (0.8 °C) in July. These differences may be considered negligible, with elevational and other topographic influences more important. Across the width of Montana, however, the free-air temperatures in July over Glacier Park average about 8 °F (4.5 °C) lower than those at similar altitude (a.s.l.) over Yellowstone Park.

Local Topographic and Site Effects.—Local variation in average temperature are shown in table 6 for the Coram Experimental Forest (Coram) area. The average (estimated normals) for the Coram stations are derived from hygrothermograph data covering periods of 4 yea or slightly longer. (Some highly suspect data, attribute to calibration problems, were excluded.)

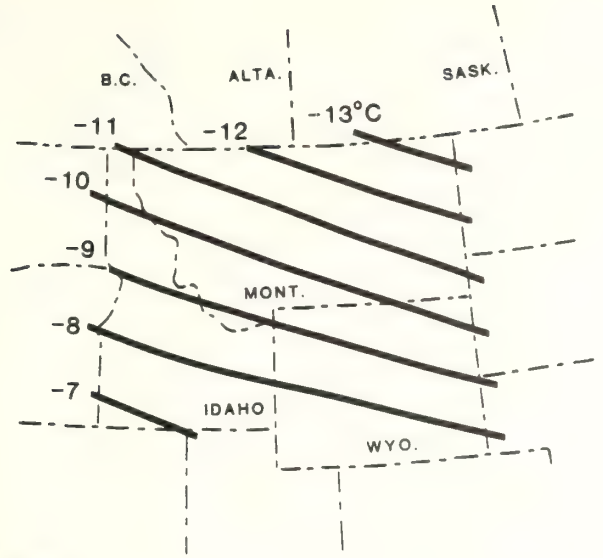
Among the Coram stations, average maximums in December-January show a decrease of only 1.2 °F (0.7 °C) between the clearcut sites at 3,950 ft (1 200 m) and 5,200 ft (1 585 m), apparently reflecting frequent daytime temperature inversions. The averages decreas 5.7 °F (3.2 °C) between the two sites in July-August. Strong nighttime inversions are indicated in summer, with average minimums 7 °F (4 °C) higher at the upp clearcut. These inversions are also evident in winter; t smaller average difference in minimum temperature obscures the large inversion magnitudes that can occu on clear, calm nights during this generally cloudy tim of year.

Near the Continental Divide, temperature data from the Upper Columbia Snow Laboratory (table 28, appe dix) show a similar local pattern. The December-Janu

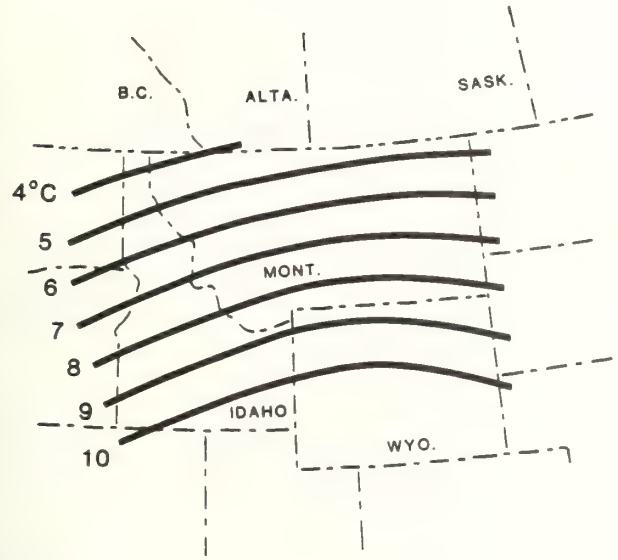
Table 5.—Average temperatures and lapse rates in free atmosphere, observed at Great Falls, MT, and Spokane, WA; values for and between 850- and 700-mb pressure levels, winter and summer months. Based on soundings near 2000 m.s.t. during 1946-56 and near 0500 m.s.t. during 1957-70.[1] T is temperature, °F; Ht, average altitude of pressure surface, in tens of feet above sea level; LR, lapse rate, in °F per 1,000 ft

		Great Falls					Spokane				
		850 mb		700 mb		850-700	850 mb		700 mb		850-700
Month	Time	T	Ht	T	Ht	LR	T	Ht	T	Ht	LR
January	0500	23.5	475	12.3	971	2.3	26.2	478	13.6	976	2.5
	2000	21.0	472	10.1	966	2.2	22.9	475	11.9	969	2.2
July	0500	61.7	493	42.4	1,026	3.6	60.7	494	39.4	1,023	4.0
	2000	67.7	491	44.8	1,028	4.3	64.1	495	40.2	1,025	4.5
August	0500	61.0	491	42.2	1,023	3.5	59.6	492	39.3	1,021	3.9
	2000	66.8	491	43.8	1,026	4.3	63.1	493	39.6	1,023	4.4

[1]January data observed at 2000 m.s.t. through 1957.



JANUARY



JULY

Figure 27.—Average temperature pattern (°C) in free atmosphere at 700-millibar pressure level (near 10,000 ft) over Northern Rockies, for January (A) and July (B). Based on 5 a.m., m.s.t., data for 13 years 1958-70; data were temperature values interpolated for 16 point locations from individual maps in monthly Climatological Data, National Summary.

average maximum decreases 2 °F (1.2 °C) between headquarters at 4,840 ft (1 476 m) and "station 10" at 6,340 ft (1 933 m), compared with a decrease of 6.7 °F (3.7 °C) in July-August.

Effects of slope aspect and timber cover are difficult to discern with the above stations. Findings elsewhere in the Northern Rockies, in the Priest River area of northern Idaho, are cited by Finklin (1983b). For example, the average diurnal temperature range during July-August was 9 °F (5 °C) greater in a clearcut than under an adjacent full-timber canopy, though 24-hour average temperatures were nearly identical.

Also showing local effects are data from 20 valley and slope stations in the Kananaskis Valley area of Alberta (MacHattie 1970); the data cover just one summer. July-August average maximum temperatures differed from their regression-line estimates by between 2.5 and 3.5 °F (1.5 and 2.0 °C) at six of the stations (present author's calculations). The overall lapse rate was 4.3 °F per 1,000 ft (7.8 °C per 1 000 m), identical to that in figure 26, but the temperature-elevation correlation was only −0.78.

The local variation that can occur on individual days is illustrated by measurements in the Many Glacier vicinity, on a clear, unusually hot July afternoon in 1960. Temperatures along the lower part of the Grinnell Glacier trail varied as much as 10 °F (6 °C) within a 1-mile (1.6-km) distance. The readings, taken in the shade, appeared to be influenced by the proximity and density of timber cover and also air movement off cool lakes (Josephine and Swiftcurrent). Earlier that afternoon, a marked local cooling effect of Grinnell Glacier was shown by readings (5 ft [1.5 m] above the snow-covered surface) as low as 59 to 61 °F (15 to 16 °C), compared with 79 to 82 °F (26 to 28 °C) in the nearby picnic area, close to precipitation gauge No. 1 (fig. 12). A strong temperature inversion during the preceding night was indicated by observed minimums of 63 °F (17 °C) inside the shelter at the gauge site and 44 °F (7 °C) at the Many Glacier campground. (Above data are from the author's original notebook.)

A moderating lake effect and exposure to breezes may explain the difference between the two stations at Many Glacier listed in table 28 (appendix). At the original station site, by the northeast shore of Swiftcurrent Lake, July and August maximum temperatures average up to 2.5 °F (1 °C) lower than those at the more sheltered Ranger Station (fig. 6); minimum temperatures average about 5 °F (3 °C) higher. Similar effects are indicated in Waterton Park, where the July-August minimums at Headquarters average about 6 °F (3 °C) higher than those at Waterton River Cabin.

Table 6.—Topographic and local site differences in average temperatures; in Coram Experimental Forest (Abbott Creek drainage) and vicinity, near west edge of Glacier National Park. Averages based on or adjusted to 30-year normal period, 1951-80

Station[1]	Elevation above Sea level	Elevation above Creek	Aspect	Slope	Site description	Average temperatures[2] Dec.-Jan. Max. Min. Mean	July-Aug. Max. Min. Mean	Annual Max. Mi Mean
	Feet			Pct		°F		
Hungry Horse Dam	3,160					30.2 17.6 23.9	79.2 49.0 64.1	53.0 32 42.7
West Glacier	3,180			0	In clearing, tall trees nearby	28.6 15.0 21.8	76.9 45.5 61.2	51.7 29 40.8
Spacing study	3,900		NW	20	In thinned 15-year-old larch stand		78.3 44.6 61.3	
Abbott Creek	3,950	20	W	5	Open area (clearcut), shrubs and young birch	27.2 15.2 21.2	76.3 43.0 59.7	
60-acre clearcut	[3]4,150		N	20	Clearcut within thinned 15-year-old larch		77.2 43.6 60.7	
Group selection	4,250	300	E	50	In 2-acre cutting unit, burned; subalpine fir type	28.2 21.0 24.6	75.5 51.3 63.4	49.8 3 42.4
Uncut	4,450	400	E	60	In mature timber, subalpine fir type	25.8 18.4 22.1	72.5 52.3 62.4	47.6 3 41.2
Shelterwood	4,900	800	E	50	About 50% harvested, understory burned; subalpine fir type	26.2 18.9 22.6	70.3 50.3 60.3	46.1 3 39.9
Clearcut	5,200	600	E	80	Near center of 17-acre clearcut, burned; subalpine fir type	26.0 18.3 22.2	70.6 50.4 60.5	46.1 3 39.7
Desert Mtn.	[4]6,350		S	5-10	Generally open		67.5 48.4 58.0	

[1]Listed in order of increasing elevation; Coram stations are those at 3,900 to 5,200 ft.
[2]All averages are based on or adjusted to midnight-midnight observation day. Data for Coram stations, from varying periods mostly during 19's were obtained by hygrothermographs (see text). To compensate for the generally slower instrumental response, as compared with standard liqu glass thermometers, the Coram average maximum temperatures might be raised 1 °F; the minimum temperatures lowered 1 °F.
[3]Location in broad draw bottom.
[4]Location on ridgeline about 300 ft south of lookout.

Extreme Temperatures.—Highest monthly mean temperatures recorded to date around Glacier Park generally occurred in July 1936 (table 7). These means, as high as 69 °F (20 °C), were 5 to 6 °F (3 °C) above the present July normals. Lowest means occurred in January 1937 on the west side, near or slightly below 0 °F (−18 °C), and in January 1950 on the east side, near −10 °F (−23 °C); these were about 20 to 25 °F (11 to 14 °C) below normal.

Observed highest and lowest daily temperatures, by months, are included in tables 18 and 30 (appendix).

Annual extreme values are summarized in table 8. Ma mum temperatures during the past 50 years have reached as high as 102 to 105 °F (about 40 °C) near t west edge of Glacier, generally slightly lower near th east edge. In an "average" year, these areas have an extreme somewhere near 90 to 95 °F (32 to 35 °C). A higher elevations, 85 °F (20 °C) has been observed at 7,500 ft (2 280 m), at Mount Brown Lookout. Minimu temperatures near the park edges have gone as low a −40 to −55 °F (−40 to −48 °C); in an average year extremes ranging from −22 to −38 °F (−30 to −39

Table 7.—Extreme monthly mean temperatures[1] observed in Glacier National Park vicinity; highest and lowest, °F, since 1931; Dep. is departure from 1951-80 normal

Station	High mean	Dep.	Month, yr	Low mean	Dep	Month, yr
Babb 6NE	65.7	+6.0	July 1936	−11.8	−28.6	Jan. 1950
Browning	68.3	+6.1	July 1936	−8.4	−25.3	Jan. 1950
Polebridge	65.2	+4.7	July 1936	−3.0	−20.1	Jan. 1937
Summit	62.2	+5.4	Aug. 1961	[2]−6.0	−20.6	Jan. 1950
West Glacier	69.1	+6.0	July 1985	1.1	−19.4	Jan. 1937

[1]Calculated as arithmetic means of the average daily maximum and minimum values, based on 24-hour periods ending about 5 p.m.
[2]Includes estimate for 1 day of missing data.

may be expected. The annual minimums are much more variable from year to year than are the maximums, as indicated by the standard deviations in table 8.

FREEZING TEMPERATURE THRESHOLDS

Table 9 indicates that the period without any freezing temperatures, 32 °F (0 °C) or lower, averages 3 months or less. Valley locations such as Polebridge and Summit, subject to ponding of nighttime cool air drainage (Schroeder and Buck 1970; Geiger 1965; Yoshino 1975), experience freezing temperatures during every month of the year. For the threshold of 28 °F (−2 °C), sometimes used to define a "killing frost" for agricultural and fire-weather purposes, the open period averages about 4 months (mid- or late May to mid-September) near the east edge of Glacier Park; between 2½ and 4½ months in west-side valley locations. Standard deviations in table 9 indicate that in two-thirds of the years, the various threshold temperatures will occur within about 2 weeks of the average dates; lengths of season between the freezes will be within about 3 weeks of the average. Longer seasons can be expected on adjacent slopes, in connection with nighttime temperature inversions and "thermal belts."

Table 8.—Annual extreme maximum and minimum temperatures, °F. Average (Avg.), standard deviation (SD), and highest and lowest observed. Based on available data during 1931-80 or indicated years

	Extreme maximum				Extreme minimum			
Station	No. yrs	Avg. annual	SD	Highest, mo, yr	No. yrs	Avg. annual	SD	Lowest, mo, yr
Babb 6NE	47	90.5	3.1	99 Aug. 1969	50	−33.6	7.9	−52 Jan. 1950
Browning	48	91.4	3.0	98 July 1934	48	−30.5	7.5	−44 Jan. 1950, 72
Polebridge	38	93.8	4.1	102 Aug. 1969	39	−34.2	8.6	−46 Jan. 1950, 57
Summit	43	87.6	3.4	96 Aug. 1961, 69	42	−38.5	8.5	−55 Jan. 1959
West Glacier	50	92.3	3.2	101 July 1934	50	−21.5	10.3	−40 Feb. 1933
Essex (1958-70)	13	95.9	3.8	105 Aug. 1961				
Many Glacier (1968-73)	4			92 Aug. 1969	6			−50 Jan. 1972
Saint Mary (1964-83)	18	92.4	3.6	103 Aug. 1969	12			−43 Jan. 1972
Sherburne Lake (1939-51)	13	86.7	3.4	92 Sept. 1950				
Waterton Park HQ (1951-74)	19			95 Aug.[1]	19			−37 Jan., Dec.[1]
Desert Mtn. LO (1936-73)	37	82.8	3.4	94 Aug. 1969				
Mt. Brown LO (1931-57)	24	75.6	3.7	85 July 1934				
Sperry Chalet (1960-75)	15	81.7	3.6	90 Aug. 1961				

[1]Year of occurrence not available.

Table 9.—Freezing temperature thresholds. Mean, median (Med.), earliest recorded, and latest recorded dates of last-spring and first-autumn occurrences of specified minimum temperatures (Min.), °F; season division taken as July 31. For period 1951-80 (with 29 or 30 years of data), except as noted. SD is standard deviation, days. E denotes estimated due to missing data

Station	Min.	Date of occurrence[1]										No. days intervening	
		Last in spring					First in autumn						
		Mean	SD	Med.	Earli-est	Lat-est	Mean	SD	Med.	Earli-est	Lat-est	Mean	SD
Babb 6NE	32	6/21	17	6/20	5/18	7/26	8/28	12	8/31	8/ 1	9/20	68	21
	28	5/27	19	5/21	4/24	7/ 6	9/16	12	9/18	8/25	E10/ 8	112	23
	24	5/ 6	14	5/ 6	4/12	6/11	9/28	12	9/28	9/ 3	10/22	146	18
	20	4/24	15	4/25	3/31	6/ 7	10/ 7	13	10/ 8	9/12	11/18	166	21
	16	4/13	15	4/12	E3/14	5/10	10/17	18	10/13	9/12	11/18	187	24
Browning	32	6/ 8	18	6/ 6	5/13	7/31	9/ 6	12	9/ 8	8/ 2	9/23	90	22
	28	5/18	15	5/19	4/24	6/30	9/19	11	9/18	9/ 3	10/19	124	18
	24	5/ 4	13	5/ 4	E4/ 8	5/29	9/29	14	10/ 1	9/ 3	10/27	147	20
	20	4/21	14	4/23	3/15	5/13	10/ 9	15	10/10	9/14	10/27	170	21
	16	4/15	15	4/14	3/14	5/13	10/24	17	10/24	9/14	11/28	192	25
Polebridge	32	7/15	16	7/18	5/30	7/31	8/12	10	8/ 9	8/ 1	9/ 7	28	19
	28	6/17	21	6/13	5/12	7/31	9/ 2	12	9/ 3	8/13	10/ 2	78	21
	24	5/14	13	5/11	4/23	6/14	9/23	12	9/24	9/ 3	10/17	133	16
	20	4/27	13	4/29	3/28	5/29	10/ 5	17	10/ 6	9/ 3	11/ 9	161	21
	16	4/12	12	4/14	3/17	5/ 2	10/20	17	10/22	9/14	11/23	189	21
Summit (1951-78)	32	7/20	13	7/25	6/14	7/31	8/10	10	8/ 8	8/ 1	9/ 8	21	18
	28	6/28	24	7/ 1	5/10	7/30	8/21	16	8/19	8/ 2	9/24	54	28
	24	5/24	18	5/23	4/21	7/ 8	9/13	15	9/ 9	8/19	10/23	112	25
	20	5/ 9	17	5/ 6	4/ 1	6/13	9/28	17	9/30	9/ 2	10/30	142	22
	16	4/27	14	4/29	4/ 1	6/ 1	10/ 7	17	10/ 7	9/ 3	11/ 5	162	21
West Glacier	32	6/ 6	17	6/ 2	5/ 5	7/19	9/12	11	9/13	8/16	10/ 1	98	20
	28	5/13	14	5/11	4/17	6/13	9/28	13	10/ 1	9/ 4	10/22	138	20
	24	4/21	12	4/22	3/28	6/ 1	10/16	16	10/17	9/14	11/14	178	23
	20	4/ 7	14	4/ 8	3/15	5/ 2	10/30	15	11/ 1	9/14	11/28	206	19
	16	3/25	16	3/23	2/17	5/ 1	11/14	14	11/13	10/22	12/23	234	21
Mullan Pass (1942-57 for 32; others 1948-57)	32	6/21	12	6/25	5/29	7/12	9/16	4	9/16	9/11	9/24	87	13
	28	6/ 7	11	6/ 7			9/29	12	9/28			114	21
	24	5/ 8	10	5/ 4			10/ 9	17	10/10			154	15
	20	4/21	16	4/21			10/29	17	10/30			191	23
	16	4/10	13	4/ 6			11/ 6	13	11/ 4			210	14

[1]Month number/day number; thus 6/14 is June 14.

SOIL TEMPERATURE; STREAM TEMPERATURE

The annual regime of soil temperature measured at the former Upper Columbia Snow Laboratory is portrayed in figure 28A. Though based on a short period of record, the monthly means should represent the pattern in similar forest areas near 5,000 ft (1 500 m) elevation. Monthly mean air temperatures at UCSL headquarters are included for comparison. Average diurnal ranges in soil temperature reached about 25 °F (14 °C) at the ground surface in July-August but only 4 °F (2 °C) at a 6-inch (2.4-cm) depth; 1 °F (0.6 °C) at 2 ft (61 cm).

Most notable are the relatively high soil temperatures in winter, showing the insulating effect of the heavy snow cover and the surface vegetation (grass and brush). Temperatures at the soil surface barely fall to 32 °F (0 °C), and a few inches below this the ground evidently remains unfrozen. Snow cover during the corresponding 4 years (1947-49 and 1951) was generally above the estimated normal, but this apparently did not matter; winter soil temperatures were similar with below-normal snow cover (in 1948). As shown in figure 21, the snow cover at nearby Summit averages about 15 inches (38 cm) by December 1, retarding the soil temperature decrease prevailing into November (fig. 28A).

Mueller (1970) shows a similar effect of snow cover at sites (soil plots) elsewhere in western Montana, between Superior and Mullan Pass, using 20-inch (50-cm) temperatures. Air-soil temperature differences were, however, larger at UCSL—because of the lower air temperature here. Interpolated for a 20-inch depth, these differences average 16 °F (9 °C) during December-February.

During spring and summer, portrayed soil temperatures average lower than those of the air, with the difference reaching 5 or 6 °F (3 °C) at 20 inches. (The difference was twice as large at five of Mueller's plots.) For the year, temperatures at 20 inches average 40 °F (4 °C) or 4 °F higher than the air temperature; this is identical to the 20-inch average at Coram Experimental Forest upper clearcut station (Hungerford and Schlieter 198

Interpolation in figure 28A gives an average period of about 127 days (June 8-October 12) with 20-inch (50-cm) soil temperature 42.0 °F (5.5 °C) or higher—a threshold considered significant for vegetative growth (Mueller

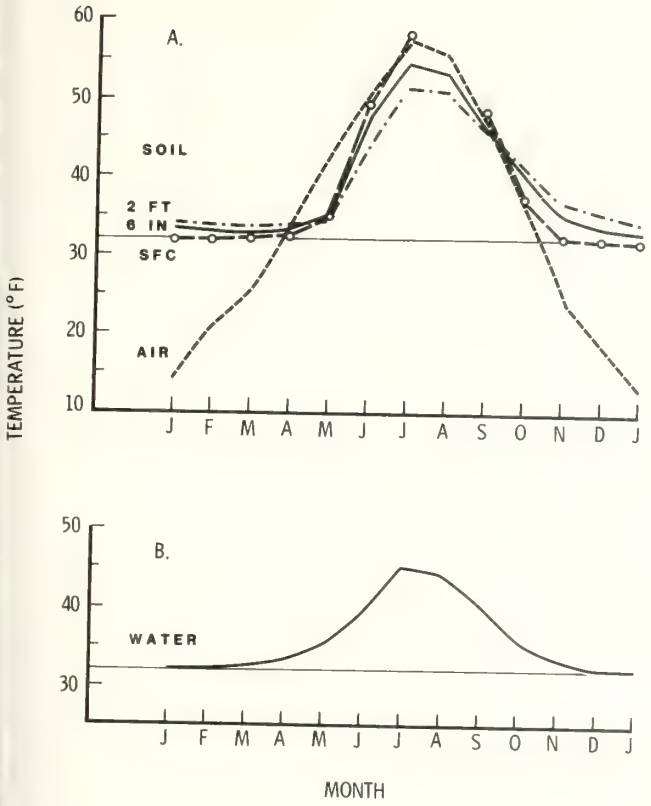


Figure 28.—Panel A: Monthly mean soil temperatures near Marias Pass—at former Upper Columbia Snow Laboratory, "station 39," in spruce, larch, and lodgepole forest passageway about 25 ft (7 m) wide. At indicated depths; based mostly on 2 to 4 years during 1947-51. Comparative mean air temperatures are at nearby headquarters, 4 ft (1.2 m) above ground or snow surface, adjusted to normal period 1951-80. Thin horizontal line is drawn at 32 °F (0 °C). Panel B: Same, for water temperature of Skyland Creek (at flume), near headquarters; based on 2 to 3 years.

70). This duration is similar to that—124 days—found at Mueller's coolest site, at almost the same elevation.

Rather high ground-surface temperatures may occur during summer days at open sites, particularly on southerly slopes. On a southwest-facing grassland slope, 7,100 ft (2 165 m) in southwestern Montana, Mueggler (1971) shows daily maximum temperatures of a bare soil surface averaging 127 °F (53 °C) in July and 119 °F (48 °C) in August—the daily minimums averaged about 40 °F (2 °C). Under artificial shade nearby, July and August soil-surface maximums averaged 77 °F (25 °C); minimums about 45 °F (7 °C). Temperatures at a 20-inch (50-cm) depth had May-October averages similar to those at UCSL. On summer days in the Coram Forest, Ingerford and Schlieter (1984) report that litter-surface temperatures on unvegetated clearcuts often reached 140 °F (60 °C); monthly average daily maximums sometimes exceeded 115 °F (46 °C).

Figure 28B gives an example of monthly average temperature of a small mountain stream—again near the UCSL headquarters. The annual curve, like that of soil temperature, shows a limiting lower value of 32 °F (0 °C) in winter; flow of water continues. Average temperatures rise to only 45 °F (7 °C) in July and August, apparently more indicative of soil temperatures at the stream's sources (Geiger 1965); Skyland Creek's various branches or forks emerge at elevations generally near 6,000 to 6,500 ft (1 800 to 2 000 m). This stream has an average diurnal temperature range of 5 or 6 °F (3 °C) in July and August, with water temperatures averaging 47 or 48 °F (9 °C) in midafternoon. Highest on any day during the two summers of record was 52 °F (11 °C).

Relative Humidity

The only year-round relative humidity data available within or close to Waterton-Glacier are from the Upper Columbia Snow Laboratory. Though based on only 2 to 4 years, the monthly averages, smoothed and plotted in figure 29, do follow the general trend shown by longer records at the adjacent Kalispell and Cut Bank, MT, airport stations. Relative humidity tends to vary inversely with temperature (Schroeder and Buck 1970; Finklin 1983a), and this largely accounts for the early morning-afternoon differences seen in figure 29; also for the higher afternoon values at higher elevations as at UCSL

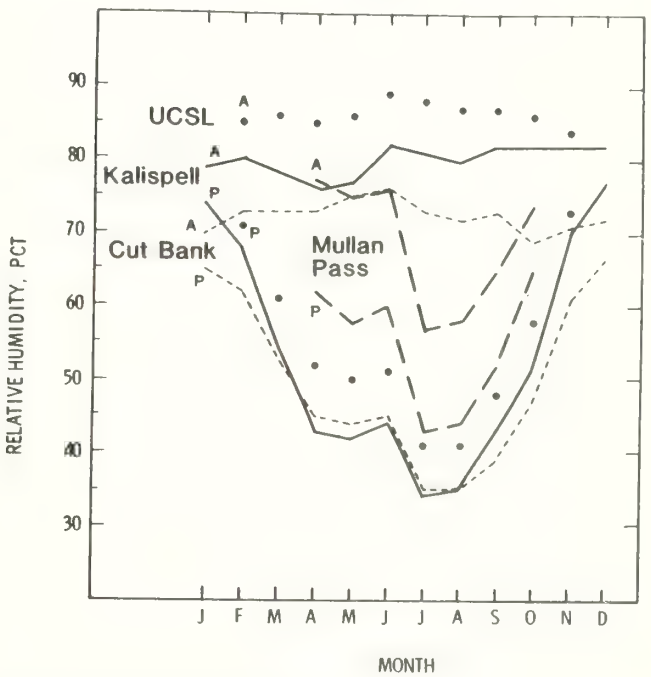


Figure 29.—Monthly average relative humidity; annual regime. Averages at 5 a.m. (A) and 5 p.m. (P), m.s.t.; based on varying lengths and periods of record (longest, 18 years at Kalispell airport). Values at Upper Columbia Snow Laboratory (UCSL), obtained from 2 to 4 years of hygrothermograph data, have been smoothed by 1-4-1 weighting factor; similarly at Mullan Pass, ID, with published 5-year averages.

and Mullan Pass, ID, a former station at 6,000 ft (1 830 m). The much lower summer nighttime humidity at Mullan Pass is partly a result of the higher nighttime temperatures here, above the inversions affecting the valleys.

Relative humidity over the park area averages highest in the winter. Midafternoon average values during November-February are in the 60 to 75 percent range or higher; lowest averages occur near the eastern edge. The afternoon averages decrease noticeably during spring and, after a slight reversal during the showery month of June, reach July-August levels of 35 to 40 percent at lower elevations and near 45 percent at 6,000 ft (1 830 m).

TEMPERATURE AND RELATIVE HUMIDITY DURING FIRE SEASON

Averages and Frequencies of Afternoon Values.—Figure 30 shows the 10-day average midafternoon temperature and relative humidity pattern during the fire season. Though complete-season data are available only for a west-side valley area, curves for other locations appear to be generally parallel (as indicated by fig. 29). The averages reveal an accelerated change near the end of June toward the warm, dry conditions covering much of July and August. This change corresponds with the decrease in rainfall seen in figure 18. Both are related to the northward retreat of the polar frontal zone and upper-air jet stream (Schroeder and Buck 1970; Critchfield 1974).

Summer afternoon averages at fire-weather stations are mapped in figure 31. The 1600 m.s.t. temperatures average generally 2 or 3 °F lower than the maximums (midnight-to-midnight) in figure 24. An exception, at West Glacier, is attributed to an exposure difference between the two separate station locations used here. Among the 11 available stations in figure 31 (the Kalispell airport not included), the correlation between temperature and elevation is −0.99 and the overall lapse

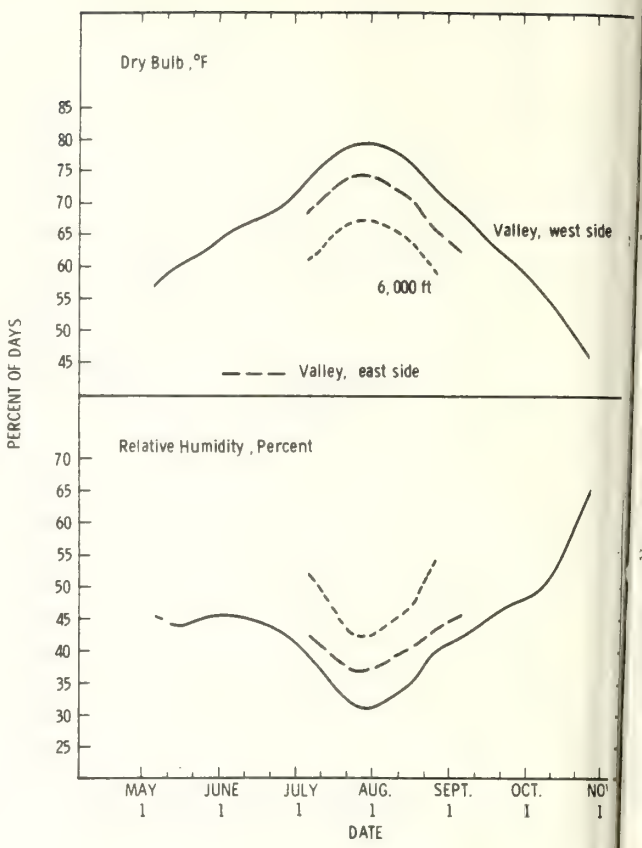
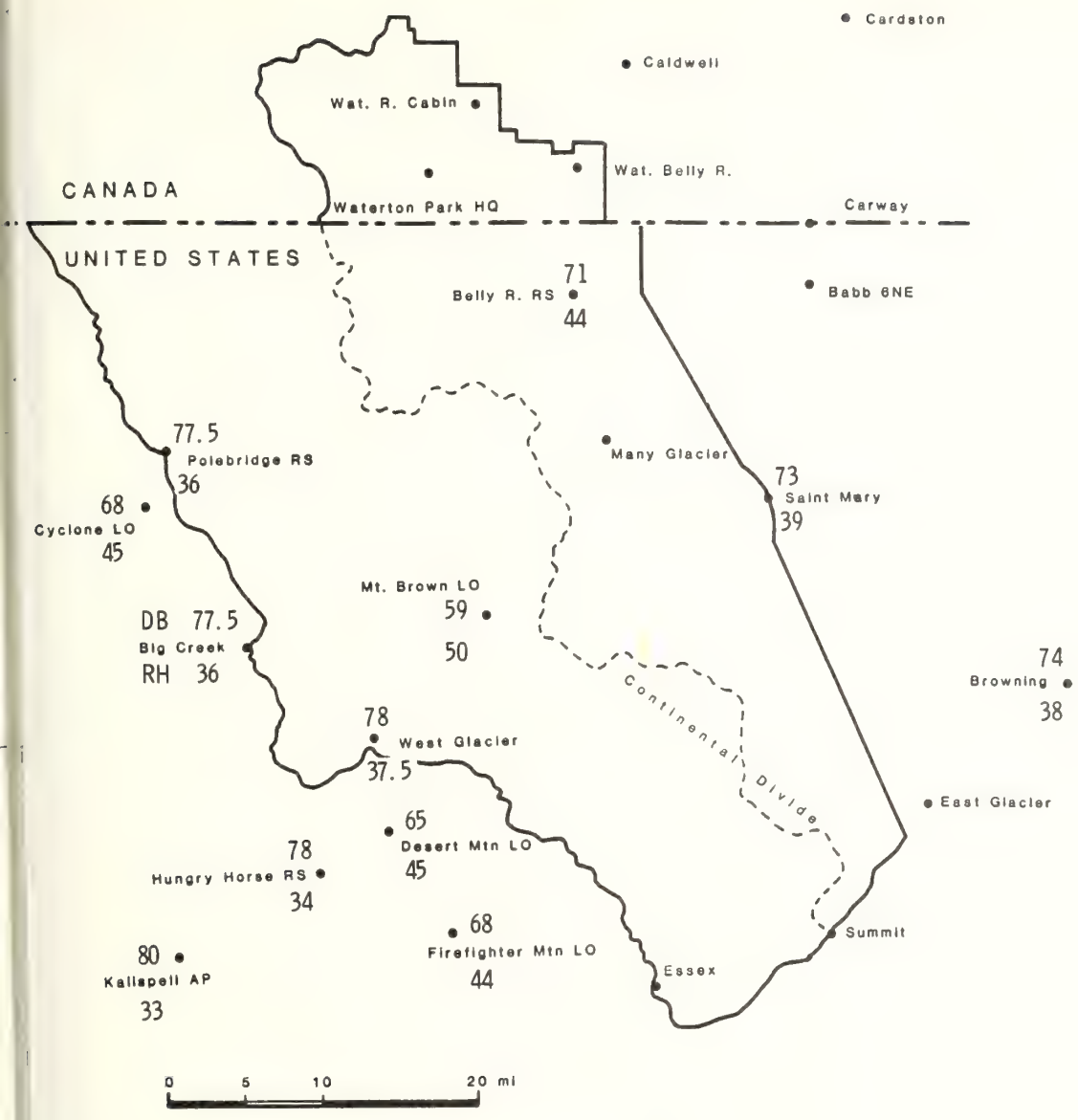


Figure 30.—Midafternoon dry bulb temperature and relative humidity; 10-day averages during fire season, smoothed by 1-4-1 weighting factor. Based on period 1951-80; mostly 1600 m.s.t. data (1300 beginning 1974). Curves for west-side valley are from combined record at Coram R.S. (1951-57) and Hungry Horse R.S. (1958-80); east-side valley, St. Mary R.S.; 6,000 ft, combined record at Desert Mountain (1951-73) and Firefighter Mountain (1975-80).



igre 31.—Average midafternoon dry bulb temperature (DB), °F, and ative humidity (RH), percent, during July. Based on or adjusted to 50 m.s.t. and period 1951-80.

rate (by regression line) is 4.2 °F per 1,000 ft (7.7 °C per 1 000 m)—close to that obtained for maximum temperatures in figure 26. The correlation found between relative humidity and elevation is 0.96, with a regression-line increase of 3.3 percent per 1,000 ft (305 m). Again, average values at specific locations can differ by several degrees or several percent from estimates based on these gradients. This variation is shown on a smaller scale by afternoon observations during one summer in the McDonald drainage (Kessell 1979). Some local effects on summer temperatures have been described earlier.

Statistics of afternoon temperature ("dry bulb") and relative humidity are given in table 33 (appendix). (Similar details for fire-season maximum, minimum, and mean temperatures are included in tables 30 and 31.) Portrayed in figure 32 is the exceptional spell of hot and dry afternoon conditions that persisted during the 10-day period August 11-20, 1967—a year of large fires in the Northern Rockies; these included the Glacier Wa Fire (Habeck 1970; Ruhle 1972). Lowest humidity recorded on any day, during this or other years, is abo 5 to 8 percent at lower elevations and 8 to 10 percent near 6,000 ft (1 830 m).

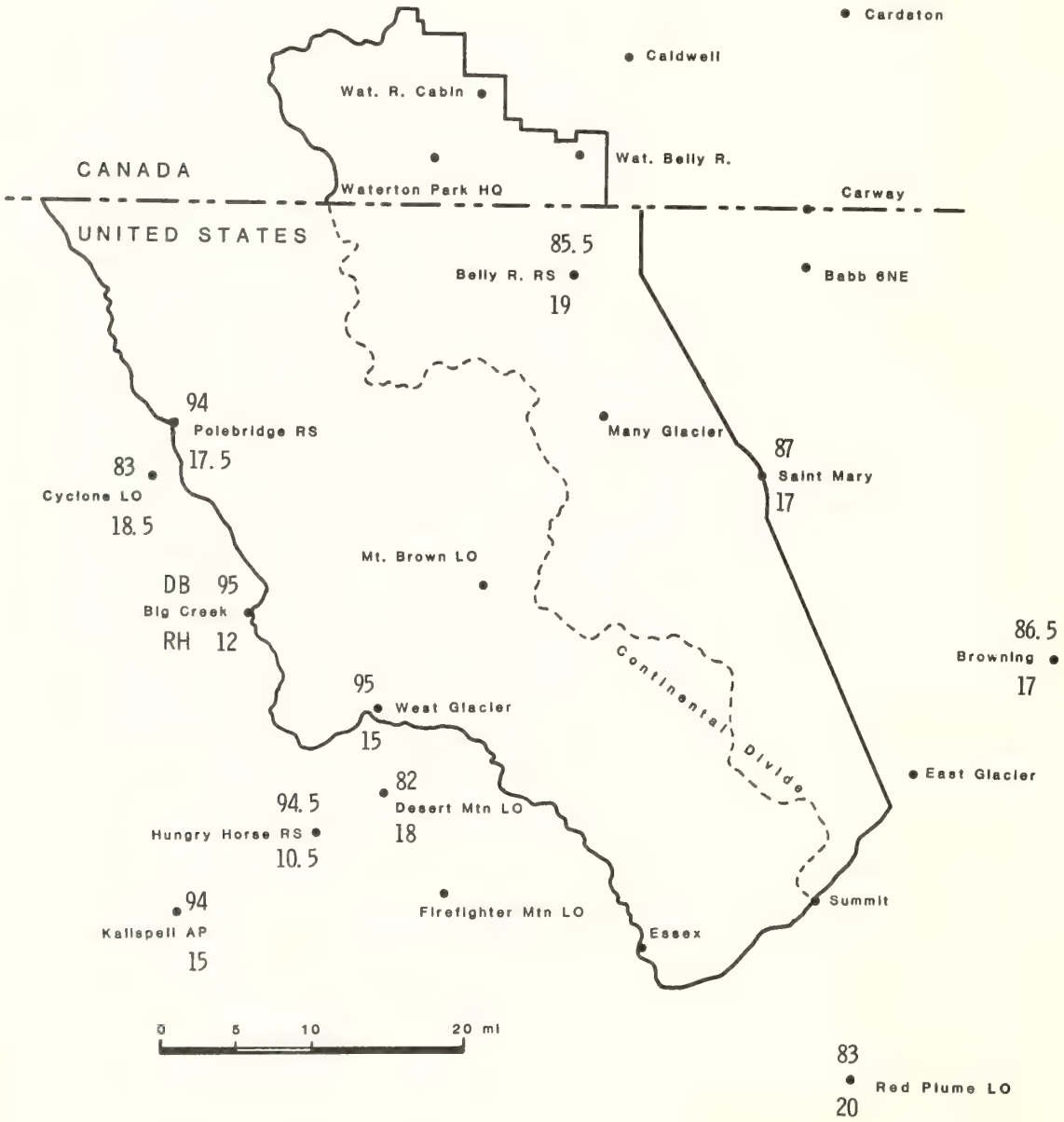


Figure 32.—Extreme 10-day average midafternoon dry bulb temperature, °F, and relative humidity, percent; observed at 1600 m.s.t., August 11-20, 1967.

The frequencies of various midafternoon temperature nd relative humidity values are shown in figure 33. The ercentages may be regarded as long-term probabilities. \ humidity below 30 percent, for example, in the west-ide valley area has about a 23 percent chance of occur-ence in mid-June; a 57 percent chance in late July and arly August; and less than a 20 percent chance by late eptember. Additional details are given in table 34 ppendix). A generally close relationship is found ig. 34) between the frequencies of certain values and he corresponding 10-day averages; the graphs do differ etween lower and higher elevations. The appropriate set f curves (or a compromise) may be used to estimate fre-uencies at other places, when given the average values.

Further, a relationship between average temperature nd the relative humidity frequency is shown in figure 5. This enables a graph-based estimate of combined dry ulb and humidity frequencies. For such an estimate, the y bulb frequency, obtained from figure 34, is multi-ied by the frequency of the humidity value. More than ne step may be necessary in each graph—for example, the prescribed temperature range includes more than ne class in figure 35 and if the humidity is specified ithin a range rather than below some threshold.

As an illustration, for the west-side valley area, the escribed afternoon dry bulb is between 70 and 89 °F; e relative humidity between 20 and 39 percent; and the time of year is August 21-31. From figure 30, the appropriate average dry bulb is 72 °F. For this average, in figure 34, the frequency of a dry bulb ≥ 70 °F is 61 percent; ≥ 90 °F, about 5 percent. Frequency of a 70-89 °F value is, thus, the difference, or 56 percent. Entering figure 35, midway between the 70-79 °F and 80-89 °F marks on the horizontal scale, the frequency of an accompanying humidity ≤ 20 percent is found to be 21 percent; frequency of humidity ≤ 40 percent, 84 percent. Frequency of 20-39 percent humidity is the difference, or 63 percent. The chance of filling the above prescription is then the product of 56 percent and 63 percent, divided by 100 percent, giving an answer of 35 percent.

The above frequencies would differ considerably under differing daily weather-map patterns—as would those of rainfall amounts and thunderstorm occurrence. There are

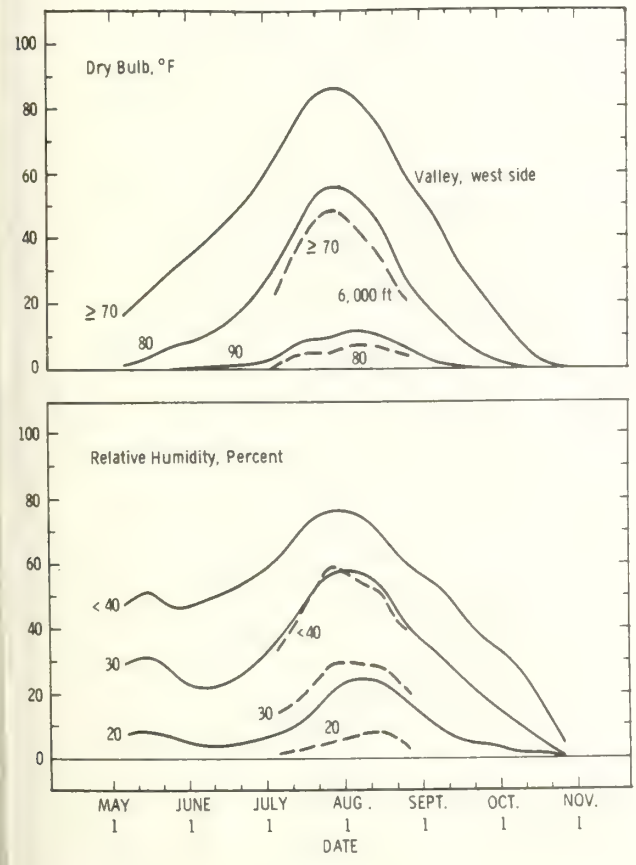


Figure 33.—Midafternoon dry bulb temperature and relative humidity; 10-day frequencies of specified values at about 1600 m.s.t. Based on years 1951-80; derived as in figure 30.

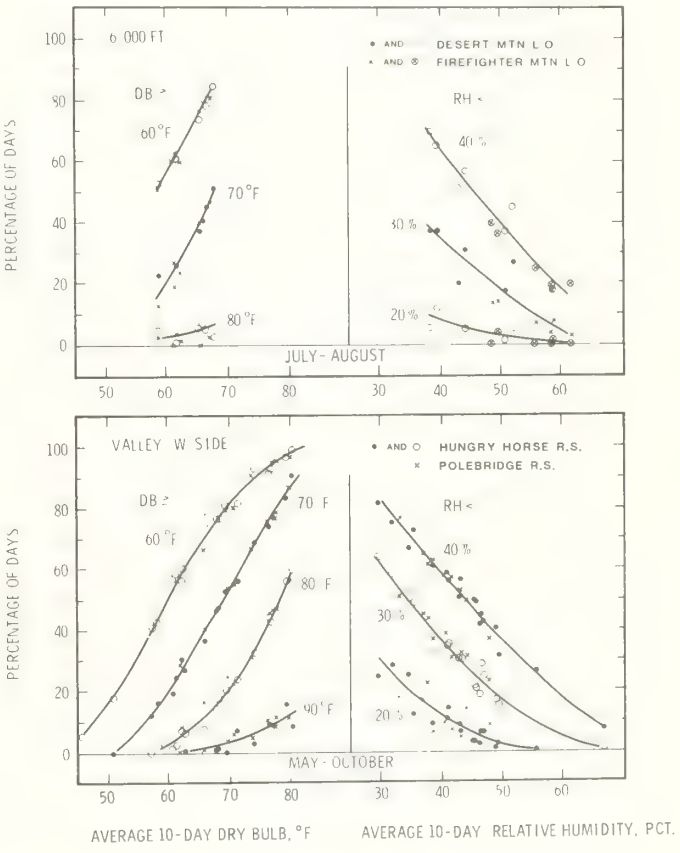


Figure 34.—Relationship between 10-day average dry bulb temperature and frequency of days with specified values (left half of figure), during indicated months of fire season, at afternoon observation time; corresponding relationship for relative humidity (right). For west-side valley area (bottom) and approximately 6,000 ft (1 830 m) (top); curves fitted by eye. Based mostly on data at 1600 m.s.t.; at 1300 beginning in 1974. Period of record 1958-80 at Hungry Horse, 1951-80 (July-September) at Polebridge, 1951-70 at Desert Mountain, and 1975-82 at Firefighter Mountain.

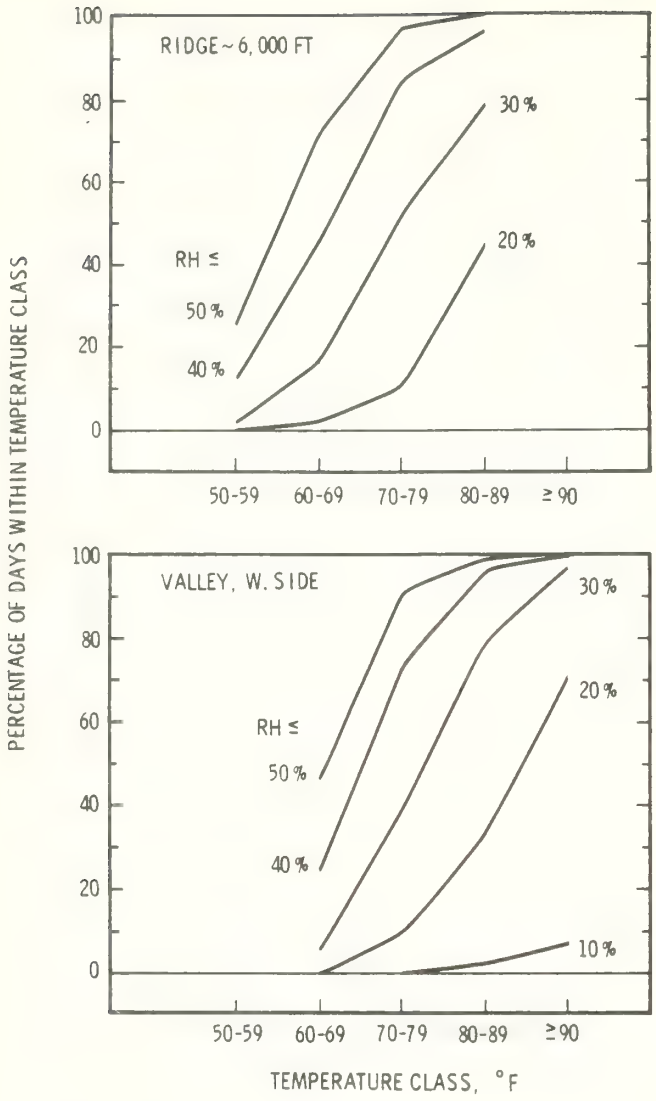


Figure 35.—Percentage frequency of July-August days with specified afternoon relative humidity, for given dry bulb temperature range (class). Data as in figure 34, except west-side valley graph represents an average based on 1951-70 period at Polebridge and 1963-82 at Hungry Horse; 6,000-ft graph based on combined record at the two lookouts.

no specific findings presented for the Glacier Park area, but a general indication of expected contrasts is given by a Selway-Bitterroot Wilderness study (Finklin 1981). For example, with an upper-air ridge over or just west of that area, the frequency of July-August afternoon humidity ≤ 30 percent at two ranger stations was about 95 percent; with an upper-air trough, the frequency was about 25 percent (compared with 63 to 64 percent for all days combined). All of these percentages are probably lower at corresponding Glacier Park locations, as inferred from figure 33 and table 34 (appendix).

Diurnal Variation of Temperature and Humidity.—Th average diurnal course of summertime temperature and relative humidity is depicted in figure 36. The contrast seen between the valley and lookout locations illustrate earlier comments about daily range, nighttime inversio effects, and the inverse variation of relative humidity with temperature. Noteworthy is the valley-ridgetop difference of 30 percent in average humidity near dawn suggested earlier in figure 29. The curves show the warmest, driest time of day is usually near 1500 to 16(m.s.t. The fire-weather observation time of 1600, in effect prior to 1974, thus tended to represent the after noon extreme conditions.

MacHattie (1966) presents some examples of local topographic and site variation in daytime and nighttin relative humidity in adjacent Alberta.

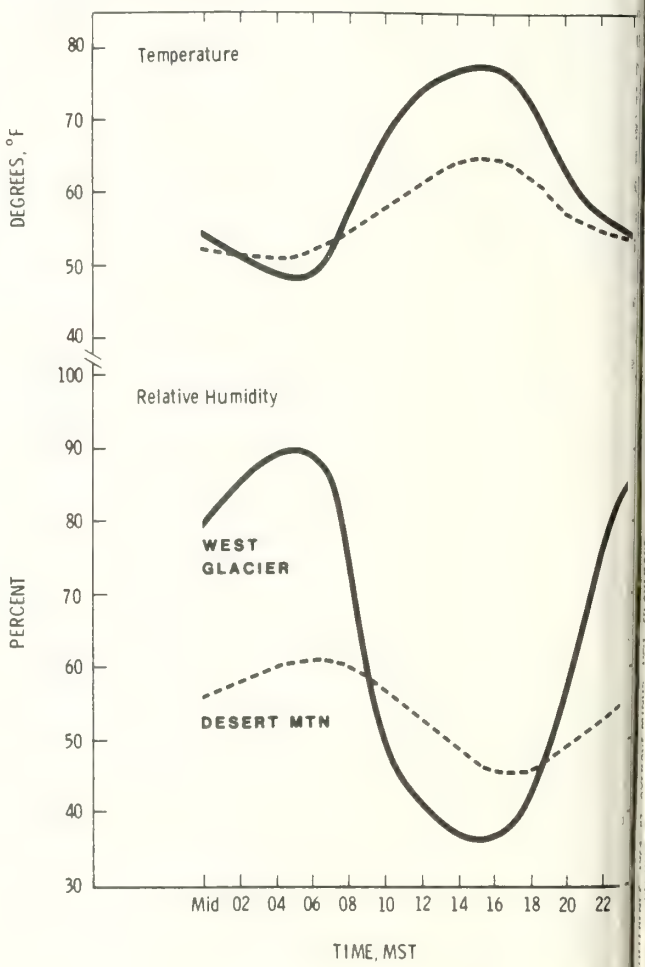
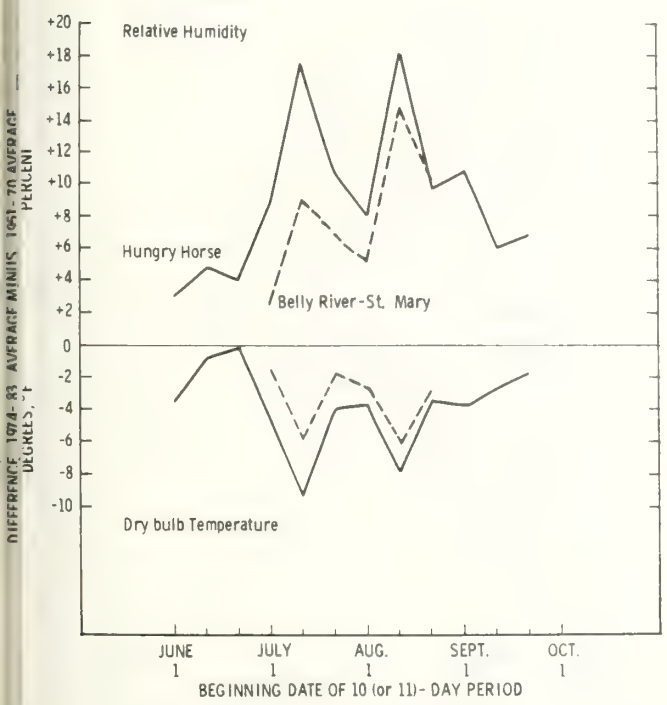


Figure 36.—Average diurnal variation of temperature and relative humidity, July and August combined, at valley and ridgetop fire-weather stations. Based on 3 or 4 years of hygrothermograph data adjusted to 1951-80 normal period.

Effects of Change in Fire-Weather Observation ime.—At the observation time now in standard use, ›out 1300 m.s.t. (1400 m.d.t.), temperatures may aver- ge about 2 °F (1 °C) lower than previously; relative ımidity, 3 to 5 percent higher (fig. 36). The time ıange will also affect the frequencies of particular ›served values. Frequencies applicable to 1300 may be ;timated with the aid of figure 34, assuming that the ıme graphic relationship holds as at 1600. For example, gure 34 indicates that in the west-side valley area dur- g September 1-10, the frequency of ≤ 30 percent ›served relative humidity is 33 percent at 1600 (when ıe average humidity is 42 percent, from figure 30). If ıe average is 4 percent higher at 1300, the above fre- ıency is reduced to 24 percent.

Figures 30, 33, 34, and 35, covering a 30-year period, raw upon a mixture of 1600 and 1300 m.s.t. data—not ıe ideal, though the balance is strongly weighted ›ward 1600 or "midafternoon." Table 10 offers some xplanation for this mixture. A large difference exists etween the 1951-70 (1600 m.s.t.) averages and the 974-83 (1300 m.s.t.) averages. In particular, July and ugust relative humidity observed on the west side of lacier averaged generally 11 to 12 percent higher in the tter period; dry bulb, about 5 °F (3 °C) lower. Only ›out one-half of the difference can be attributed to the me change (fig. 36 and diurnal curves for other North- n Rocky Mountain locations). Much can be attributed › abnormally moist and cool summer afternoons during ıe 1974-83 period. In addition, there appear to be roneously high values in some of the recent humidity data, particularly at Polebridge. (Large, obvious errors were corrected before averages were calculated.) The 1974-83 averages are compared further, by 10-day periods, in figure 37; anomalies are particularly large in mid-July and mid-August.

Thus, statistics to date for 1300 m.s.t. would probably be unrepresentative of the longer term. On the other hand, the recent cool, moist conditions and 10-day variations have their role in the standard 30-year (1951-80) climatic baseline.



gure 37.—Deviations of recent fire-weather erages, during 1974-83 at 1300 m.s.t., rela- e to averages during 1951-70 at 1600 s.t.; by 10-day periods at indicated ranger ations. Averages for Hungry Horse include 51-57 data at Coram R.S.

Wind

The pattern of monthly average windspeeds around Waterton-Glacier is depicted in figure 38. Comparisons between stations are affected by differences in period of record and anemometer exposure, but some large areal contrasts are, nevertheless, evident. (The present standard exposure [Fischer and Hardy 1976] is 20 ft [6 m] above open, level ground or nearby treetops.) These contrasts include both the actual speeds and the seasonal trends.

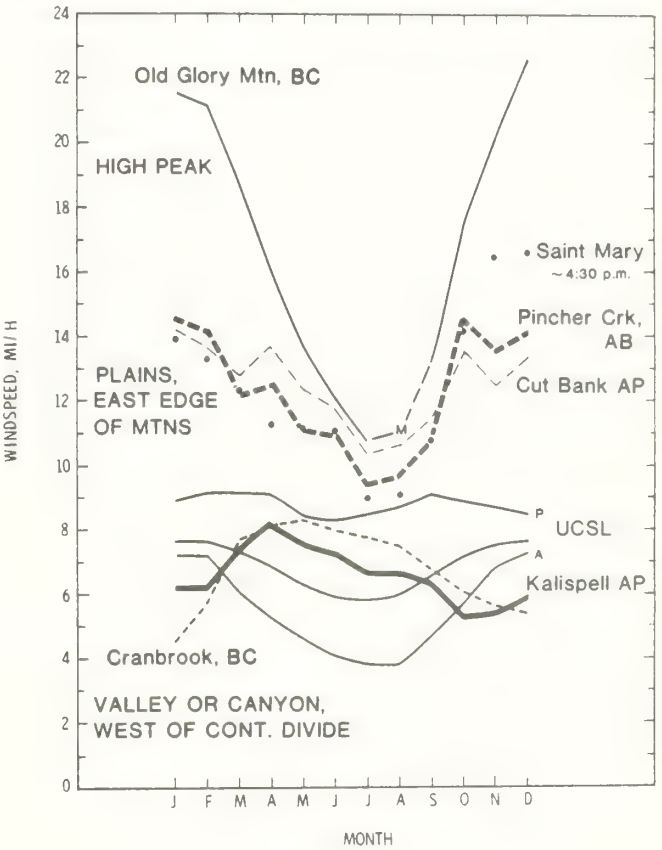


Figure 38.—Monthly average windspeed; annual regime. Speeds are 24-hour averages except as noted (M denotes missing value). Based on varying lengths and periods of record, generally between 10 and 16 years, during about 1950 to 1982. Data from Upper Columbia Snow Laboratory (UCSL), "station 1A," include 4-6 a.m. average (A) and 2-4 p.m. average (P), based on 3 or 4 years (1947-50); values here and at St. Mary have been smoothed by 1-4-1 weighting factor.

Following the trend in the free atmosphere (fig. 8), the mountains and areas east of the Continental Divide have a pronounced windspeed maximum in winter and a minimum in summer (July-August). Winds on the peaks may average near 20 mi/h (32 km/h) during November through February. The western valleys tend to have a windspeed minimum in winter, with 24-hour averages near 5 mi/h (8 km/h); a maximum in spring. In an upper canyon area just southwest of Marias Pass (at UCSL), afternoon and 24-hour windspeeds above the trees show only a small seasonal change; however, the generally lighter early morning winds have a noticeable winter maximum and summer minimum. Winds typically decrease at night over most of the park area but, conversely, they may increase on some of the high mountain terrain. Diurnal wind variation will be discussed further, among details given for the fire season.

The east side of Waterton-Glacier is noted for periods of exceptionally strong (and relatively warm) chinook winds during winter. These may gust to 100 mi/h (160 km/h) or higher—as reported, for example, at St. Mary in December 1979 and Many Glacier in December 1980; also at the Waterton Park townsite (personal communication). During the period 1972-82, St. Mary had an average of 2 days per month, November through February, with the observed 5 p.m. wind at least 40 mi/h (64 km/h). Cold north winds, however, are usually only about 5 mi/h (8 km/h) here. Strong, gusty winds may occasionally occur on the west side of Glacier—particularly with a cold airflow from the northeast (across the Continental Divide), in or near canyon or pass areas aligned with this flow.

Prevailing (most frequent) wind direction is generally from the west or southwest throughout the year, but the direction may be affected by obstructing terrain and valley or canyon orientation (as well as time of day, discussed later). Thus, winds prevail from the southwest at St. Mary, the UCSL site, and Waterton River Cabin (Poliquin 1973); from the south, most of the year, at both Cranbrook, BC, and Waterton Park Headquarters; from the northwest on Old Glory Mountain, BC.

WIND DURING FIRE SEASON

Typical summer afternoon wind conditions around Waterton-Glacier are portrayed in figure 39. Windspeeds in midafternoon average 6 or 7 mi/h (10 or 11 km/h) in the western valley area; 9 or 10 mi/h (14 to 16 km/h) on the east side. Not shown, speeds at the sheltered, former Coram R.S. averaged only 3 mi/h (5 km/h). Average speeds at the available lookouts do not show a consistent increase with elevation as may occur in the free atmosphere. Local topography is an influential factor—as in the contrast between Desert Mountain and nearby Apgar Lookout, where the speed averages twice as high at a lower elevation. A spur ridge west of Desert Mountain may break the force of the wind; while at Apgar Lookout, facing a valley constriction, the wind appears to be speeded up by a convergence effect.

Afternoon wind directions are mostly from the southwest. The dominating large-scale or "gradient" wind apparently inhibits development of an upslope "valley breeze" (Schroeder and Buck 1970; MacHattie 1968; Reifsnyder 1980) on the east side of Waterton-Glacier. An up-valley and channeling effect is indicated on the west side at Big Creek, with a southeast wind direction

Frequency Distributions.—Combined frequencies of afternoon windspeeds and directions are presented in table 35 (appendix). In addition, frequencies of various speeds may be estimated from the relationship with average speed shown in figure 40. These frequencies pe tain to the standard 10-minute average wind observed fire-weather stations in the United States. Higher spee can, of course, be expected over shorter durations and also at various other times on individual days. Illustra ing the latter condition, 1500-1600 m.s.t. windspeeds a the UCSL station (reported as 1-hour averages) were ≥ 10 mi/h (16 km/h) on 37 percent of the July-August days; for any 1-hour period between 1100 and 2000 m.s.t., this frequency was 59 percent.

"Three-way" frequencies of combined afternoon dry bulb temperature, relative humidity, and windspeed values are given in table 36 (appendix). Use of this tab may require summation over several ranges. Alternatively, these frequencies may be estimated with the ai of figure 40. The percentage obtained from this figure multiplied by that of the dry bulb and humidity comb nation, described earlier. This procedure is valid becau of a generally low correlation between afternoon windspeed and both other elements.

To illustrate, the prescribed conditions may be the previously given ranges of 70-89 °F and 20-39 percent the west-side valley area, together with a wind of less than 10 mi/h. With an average speed of 6 mi/h (from fig. 39), the desired frequency from figure 40 is 85 per cent (obtained as 100 percent minus the 15 percent fr quency for a speed ≥ 10 mi/h). The three-way frequen is thus the product of 85 percent and the previously obtained 35 percent (for dry bulb and humidity), divic by 100 percent; this gives an answer of 30 percent.

Table 10 indicates that summer afternoon windspee at Glacier Park valley locations average 1 or 2 mi/h lower at 1300 m.s.t. than at the former 1600 observat n time. The difference in periods of record may be a mi r factor here. A change in measurement, however, appe s to explain some of the 50 percent decrease in averag speed at Polebridge R.S.; a hand-held wind meter (Fischer and Hardy 1976) is now used here. Frequenc of specified higher speeds should be correspondingly lower at 1300 and, again, may be estimated from figu 40—entering at the lowered average speed.

Extreme Windspeeds.—At lower elevations, the ava ble (once-daily) observations would suggest a rather small frequency of sustained strong summertime win (≥ 25 mi/h [40 km/h])—for example, about 0.5 percen observations at Belly River and St. Mary (table 35, appendix) and even less on the west side. Such extre events are of great importance in wildfire situations—s most recently, in 1984. In the 1984 case, the August observation-time windspeeds at West Glacier, 27 mi/ (43 km/h), and Big Creek, 30 mi/h (48 km/h), were the highest for July-August in about 20 years of record. corresponding speed of 30 mi/h at St. Mary was exceeded only in July 1974—in records covering 35 s mers.

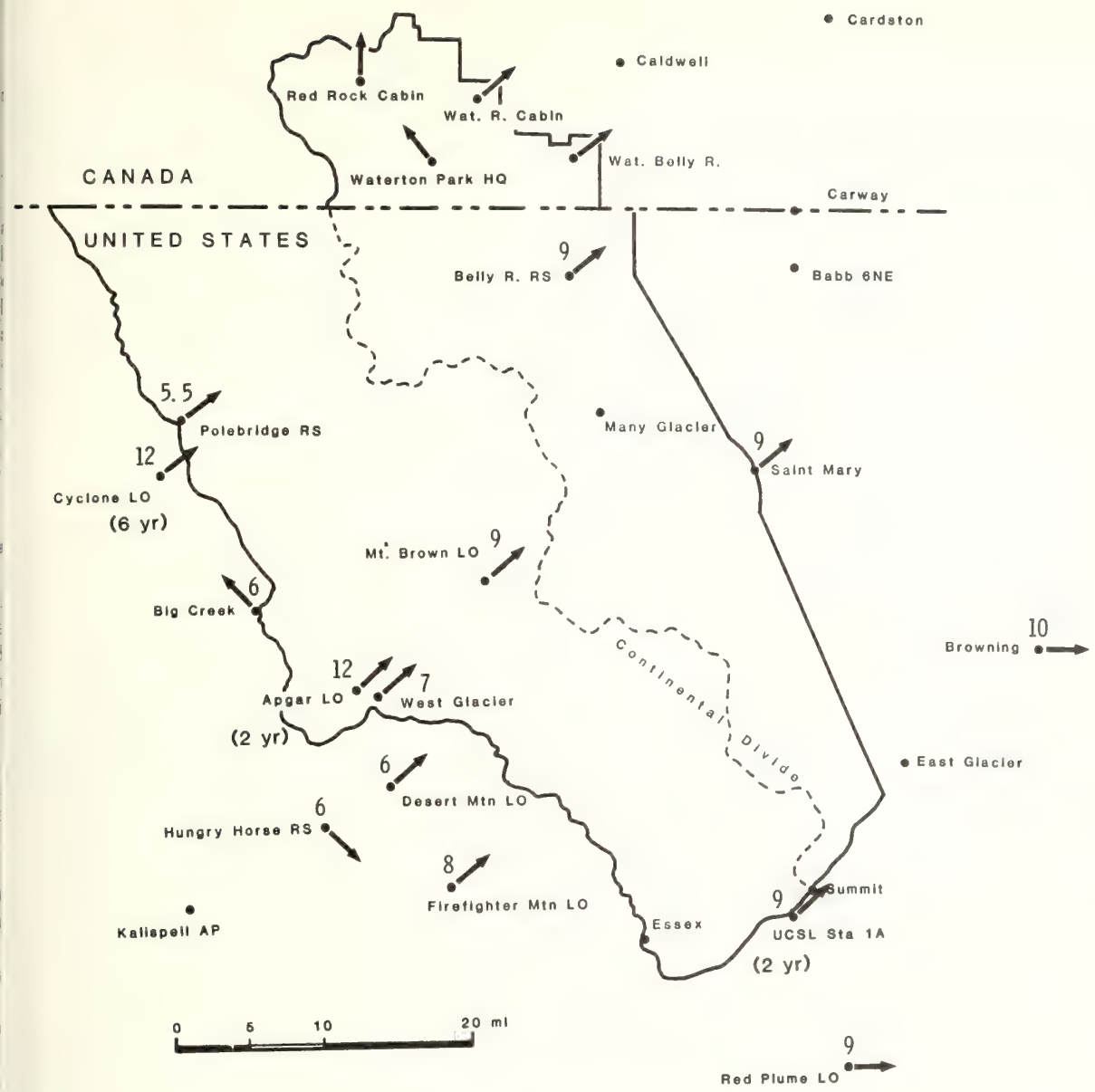


Figure 39.—July-August midafternoon average windspeed (mi/h), and prevailing direction (arrow points downwind), at 1600 m.s.t., Glacier Park area; based mostly on available 1951-70 data. Prevailing direction at Waterton Lakes stations, for unspecified time, is based on 3 to 6 years (Poliquin 1973); speed not available.

At higher elevations, the frequency of strong winds at Mount Brown Lookout (table 35, appendix) was just 1 percent (as defined above). There are, of course, windier locations, as indicated in figures 39 and 40. Maximum 5-minute average speeds at Mount Brown (Hanna 1939), recorded at any time of day, show an 8-year July-August extreme of 46 mi/h (74 km/h); this was associated with a thundershower. The average monthly extreme was 35 mi/h (56 km/h). Weather reports for the corresponding days here indicate these peak winds may occur with cool, wet conditions—as well as warm, dry.

Diurnal Variation of Wind.—Winds at the valley and canyon locations generally average highest around midafternoon (near the former fire-weather observation time) and lowest during the nighttime and early morning hours. Calm or very light summer nighttime wind conditions are common, particularly on the west side. Morning observations taken prior to 1948, at 0800 or 0900, show an average July-August windspeed of 1 mi/h (2 km/h) at Polebridge R.S.; 5 or 6 mi/h (9 km/h) at Belly River and St. Mary. Decreased early morning windspeeds have been noted at UCSL (fig. 38).

West of the Continental Divide, the summer nighttime winds are likely to have a reversed direction—with predominance of local downslope and downvalley air movement (or "drainage winds"), generally from an easterly or northerly quarter. These local winds (Schroeder and Buck 1970; MacHattie 1968; Dirks and Martner 1982; Reifsnyder 1980) are a characteristic feature of fair, settled weather. The 0400-0600 winds at UCSL showed the

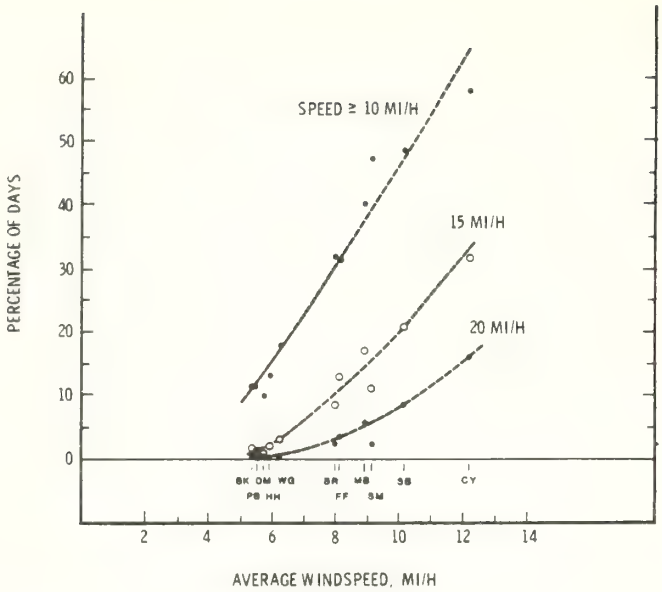


Figure 40.—Relationship between average windspeed and frequency of days with specified windspeeds, July-August afternoons. Curves fitted by eye. Based on various lengths and periods of record (generally between 10 to 20 years), with data mostly at 1600 m.s.t.; at 1300 beginning in 1974. Abbreviated station names appear along horizontal scale; most can be identified from figure 39. SB denotes Spotted Bear Mountain (south of Glacier Park).

drainage effect during July-August, with a prevailing direction from the northeast; winds from the southwest prevailed, by far, during October through April. On the east side of Waterton-Glacier, the downvalley direction is closely that of the prevailing large-scale wind, and thus summer nighttime winds tend to remain from the southwest.

Winds on some of the openly exposed ridges and mountaintop terrain may often increase during the e ning and nighttime hours (Baughman 1981). Direct d are not available, however, to document such an effe the Waterton-Glacier area. An average nighttime wir speed maximum was found at Gisborne Lookout, nor ern Idaho (Finklin 1983b). No such increase was evid

Table 10.—Monthly fire-weather averages during 1974-83 at 1300 m.s.t., compared with averages during 1951-70 at 1600 m.s.t. DB is dry bulb temperature (°F); RH, relative humidity (percent); WS, windspeed (mi/h). Freq <30 denotes percentage of days with RH less than 30 percent

		1974-83, 1300 m.s.t.[1]				Difference, 1974-83 minus 1951-70 (1600 m.s.t.)			
Station[2]	Month	DB	RH	WS	Freq <30	DB	RH	WS	Freq <30
Big Creek[3]	July	72.3	45.7	4.4	19	-5.9	+11.2	-1.8	
	Aug.	71.4	47.4	4.7	18	-5.1	+12.9	-1.7	
Hungry Horse[4]	June	66.2	47.9	3.8	18	-1.5	+4.1	-2.1	-7
	July	72.7	44.9	3.8	20	-5.9	+12.3	-2.4	-36
	Aug.	71.7	45.2	3.7	20	-4.9	+11.9	-2.0	-38
	Sept.	62.7	50.1	3.2	10	-2.8	+7.9	-1.2	-22
Polebridge	July	72.5	48.8	2.6	11	-5.4	+14.0	-2.9	-36
	Aug.	70.9	52.0	3.0	10	-5.3	+16.5	-2.5	-40
West Glacier[3]	July	73.6	47.1	5.7	11	-5.2	+10.6	-1.1	
	Aug.	72.6	47.6	5.7	15	-4.4	+11.1	-1.0	
Belly River	July	67.6	49.8	6.9	9	-2.5	+6.1	-2.0	-14
	Aug.	66.6	51.4	6.4	11	-1.9	+8.3	-2.3	-22
Saint Mary	July	68.8	44.7	8.5	25	-4.1	+6.7	-.2	-15
	Aug.	67.1	47.8	8.6	14	-4.2	+9.3	-.6	-28
Kalispell AP[5]	July	74.9 (76.8)	42.5 (39.3)	9.1		-4.0	+10.5		
	Aug.	74.0 (75.6)	42.4 (39.4)	9.1		-2.6	+9.4		

[1]Values in parentheses are corresponding averages at 1600.
[2]Ranger Stations except at Kalispell.
[3]1951-70 values estimated from 1964-73 data.
[4]Combined record at Coram R.S. (1951-57) and Hungry Horse (1958-70) used for 1951-70 data, except WS for 1958-70 only.
[5]Data for designated times interpolated from curves based on average values reported at 1100, 1400, and 1700; adjustment made for missing 1700 data during half of 1951-70 period.

Desert Mountain Lookout, from 24-hour wind record-
g charts during July-August 1936-40 (on file at the
termountain Fire Sciences Laboratory). At this some-
iat sheltered site, the charts showed an average diur-
l range from 4 mi/h (6 km/h) around 0800-1000 to 6.5
/h (10 km/h) around 1500-1700. At Mount Brown
okout, 0800 or 0900 windspeeds, possibly near their
irnal minimum, averaged 7 to 8 mi/h (12 km/h)—down
ni/h from the afternoon average.

revailing nighttime wind directions on at least the
her, dominating mountaintops and ridges should
ierally differ little from those in the afternoon. The
served morning wind at Mount Brown, most often
m the southwest, followed this pattern. A local effect
s indicated at Desert Mountain, where the prevailing
rning wind direction was from the east.

ocal Site Effects on Windspeed.—The winds just
cribed refer to those measured in open areas, though
station data may still show sheltering effects of
acent trees (and terrain). Considerably less wind can
expected within an actual, dense timber stand. An
cation of this is given by measurements at Priest River, ID (Gisborne 1941). There, the speed at 2-ft (0.6-m) and 49-ft (15-m) heights, under a timber canopy, averaged only 1 or 2 mi/h (2 or 3 km/h) on the windiest days. At the same time, winds above the treetops, measured on a tower, were near 15 mi/h (24 km/h).

Closer to Waterton-Glacier, data from the Upper Columbia Snow Laboratory (table 11) reveal some much lower average windspeeds than those previously quoted (for station 1A). Values for the other sites are from totalizing anemometers, usually read weekly. At listed stations 10 through 24, in small clearings, these instruments were situated close to a forest margin. Such locations, even on a ridgetop (station 20), may have average 24-hour speeds of just 2 or 3 mi/h (3 to 5 km/h) in summer and throughout the year. An average of 1 mi/h occurred at extremely sheltered station 12. In contrast, averages near 15 mi/h (24 km/h) were observed at an open, topographically well-exposed site—station 29. Airstream convergence through a narrow canyon area directly to the southwest may contribute to the greater wind here.

le 11.—Average windspeeds observed at various sites at former Upper Columbia Snow Laboratory; stations described by Corps of Engineers (1952b).[1] Monthly 24-hour averages based mostly on 2 to 4 years, smoothed by 1-4-1 successive weighting, except as noted

ion	Elev.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Feet	*Windspeed, mi/h*											
	4,960	7.7	7.7	7.3	6.9	6.3	5.9	5.8	5.9	6.6	7.2	7.5	7.6
	6,340	3.0	3.0	2.6	2.6	2.3	2.1	2.1	1.8	2.2	2.4	2.9	2.9
	5,300	.6	.7	.7	.8	.7	.7	.7	.6	.6	.7	.6	.6
	5,860	2.1	2.2	2.1	2.1	2.0	1.9	1.9	1.9	2.0	1.9	1.8	1.9
	5,950	2.3	2.6	2.3	2.4	2.2	2.3	2.2	2.0	2.2	2.2	2.4	2.3
	5,280	3.6	3.4	3.3	3.5	3.4	3.2	3.7	3.4	3.5	3.4	3.4	3.3
	6,075	16.9	7.9	14.4	19.2	12.8	16.7	15.3	11.4	14.9	no data		

cept as noted, stations are in clearing or near margin of forest.
emometer above tops of most adjacent trees, near headquarters
eetops 40 ft or more above anemometer.
cation on top of rounded grassy hill, highest elevation in Blacktail Hills.
sed on 1 year, averages unsmoothed. January and August data for only 2 or 3 weeks.

nshine; Solar Radiation

vember through January is normally the cloudiest
of year in the Waterton-Glacier area, July-August
learest and sunniest. This tendency refers, at least,
ouds that block out sunshine. Statistics relating to
age sky cover at adjacent airport stations (table 12),
d on all types of clouds, indicate rather cloudy con-
ns continuing into spring. Observations at the
erative climatic stations (same table), which show
clear days, apparently often excluded thin cloud
.

e normal annual pattern of sunshine occurrence, or
ion, may be approximated from figure 41. The
s—in percentages of maximum possible duration—
ot dependent on the length of daylight (sunrise to
t), which at 49° N. varies from 8.2 hours in late
nber to 16.2 hours in late June. Sunshine duration
he park near and west of the Continental Divide
d be closer to that shown at Kalispell. Noticeably greater autumn and winter sunshine occurs near the eastern edge, as at St. Mary (personal communication). Sunshine duration on the adjacent plains may approach that shown at Great Falls.

In general, the park terrain may normally receive between 20 and 35 percent of the maximum possible sunshine in December; 70 to 75 percent in July, with lowest summer amounts over high mountain areas and toward the north. Equivalent total sunshine duration is about 50 to 90 hours in December and 340 to 380 hours in July.

The above numbers apply to sunshine as detected by the standard electrical-type instruments used in the United States. These give higher values than the standard measurements of "bright" sunshine in Canada by a Campbell-Stokes (burnt-card) recorder. For example, monthly averages (Bryson and Hare 1974) for Lethbridge, AB, east of the Rockies, indicate generally 5 to 10 percentage units less duration than at similarly located

Table 12.—Monthly average cloudiness, sunrise to sunset, Glacier National Park vicinity and adjacent Montana stations. Average tenths sky cover and number of clear days (0-3 tenths cover) and cloudy days (8-10 tenths cover); observed during indicated periods of record

Station,[1] period		Tenths sky cover and numbers of days											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Kalispell	Clear	3	5	5	6	8	7	16	16	11	9	4	2
1921-48	Cloudy	22	17	16	13	11	11	3	5	11	15	20	24
Kalispell AP	Tenths	8.7	8.3	7.8	7.5	6.9	6.4	4.0	4.7	5.5	7.0	8.4	8.9
1950-82	Clear	2	2	3	4	5	7	15	13	11	6	2	2
	Cloudy	25	22	21	20	17	14	6	9	12	18	23	26
Great Falls AP	Tenths	7.3	7.5	7.4	7.4	7.0	6.6	4.2	4.8	5.6	6.4	7.1	7.3
1938-82	Clear	5	4	4	4	5	5	14	13	10	7	5	5
	Cloudy	20	18	18	18	17	14	6	8	11	15	18	19
Havre AP	Tenths	7.4	7.2	7.3	7.3	6.7	6.3	3.9	4.4	5.7	6.4	7.2	7.3
1961-70	Clear	5	5	5	5	6	6	16	14	10	8	5	5
	Cloudy	19	17	19	18	16	13	5	7	13	15	18	19
Babb 6NE	Clear	11	10	11	11	12	11	18	16	13	10	8	9
1921-48	Cloudy	8	8	8	7	8	9	3	5	7	8	8	10
Browning	Clear	13	14	14	13	13	12	19	15	14	14	11	12
1921-48	Cloudy	8	7	8	7	8	8	4	5	7	8	8	9
Summit	Clear	5	4	4	5	5	4	13	11	8	7	4	4
1935-48[2]	Cloudy	20	18	18	15	13	13	6	6	11	15	18	20
West Glacier	Clear	6	9	10	12	13	12	19	17	13	12	5	4
1921-48	Cloudy	19	15	14	11	11	9	4	5	10	14	19	22

[1]Data from first four stations are based on hourly or full-time observations; all types of clouds included. Data from last four stations are not strictly comparable; may not include thin, transparent cloudiness.

[2]Average numbers adjusted to period 1921-48.

Great Falls, MT (fig. 41). The differences are not logically related to observed cloudiness, which is also less at Lethbridge. Quite low average percentages of possible sunshine are shown closer to the Divide at Banff, AB (Janz and Storr 1977): 18 percent in December and 51 percent in July, attributed in part to topographic shading.

The annual pattern of incoming solar radiation (or insolation)—the solar energy received with sunshine and also through cloud cover—is portrayed in figure 42. The amounts shown refer to the insolation upon an unobstructed horizontal surface, as measured by an Eppley pyranometer. Amounts include the direct-beam radiation and the diffuse sky (or scattered) radiation (Reifsnyder and Lull 1965; Schroeder and Buck 1970).

Radiation values obtained close to Glacier Park at UCSL (above adjacent trees) correspond well with the trend from three surrounding stations based on longer records. The somewhat lower values at UCSL may be related to greater cloudiness; also, there is apparently a slight shading by mountain terrain, occurring early and late in the day. Otherwise, insolation should generally increase with elevation (Geiger 1965; Barry 1981); this can be expected under both clear and overcast conditions.

The daily values in figure 42 give average monthly radiation totals ranging from about 2,500 langleys (gm-cal/cm^2) in December to 19,000 langleys in July. The effect of cloudiness is evident in the relatively low June average. About 800 langleys may be received on perfectly clear, haze-free days in June and early July. The annual aggregate is about 120,000 langleys. For conver-

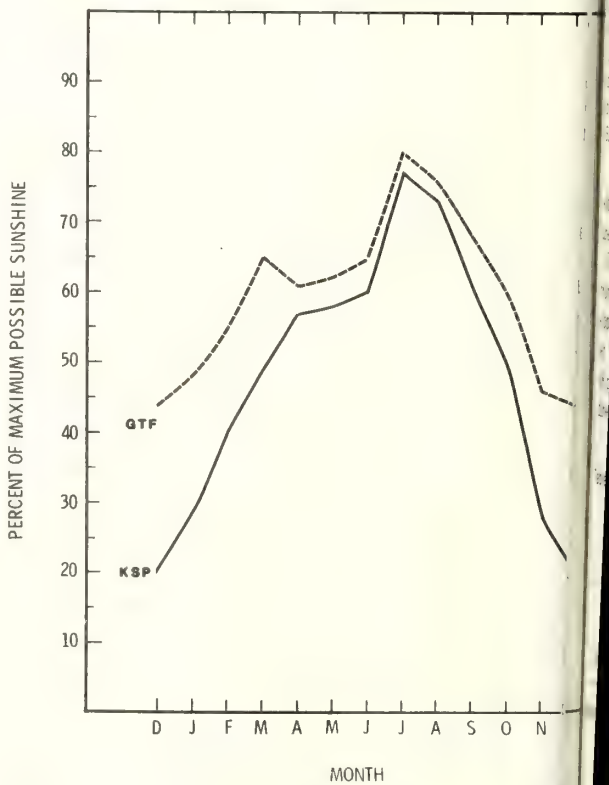


Figure 41.—Monthly average sunshine duration in percentage of maximum possible; measured by electrical-type recorders. At Kalispell, MT (KSP), based on 50 years prior to 1950; at Great Falls, MT (GTF), based on 40 years 1942-81.

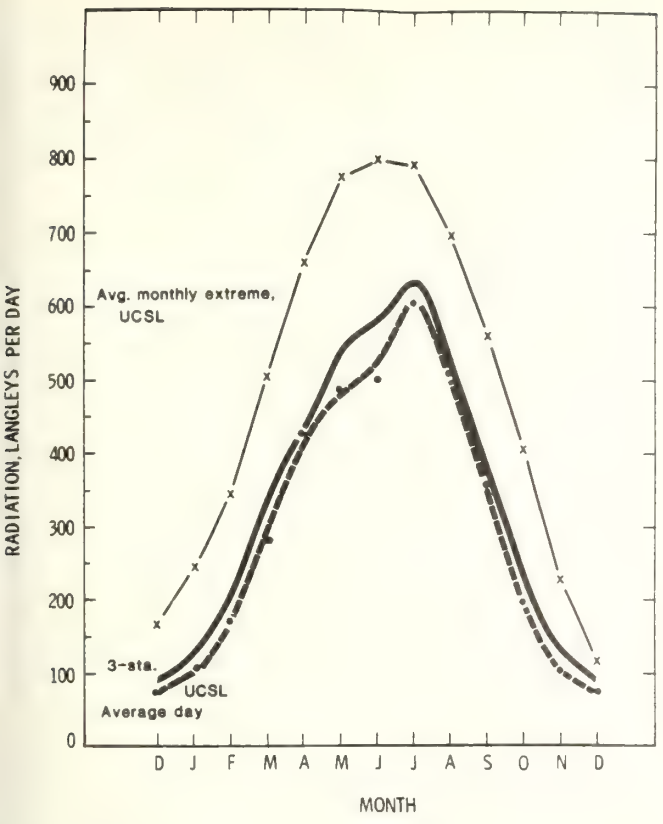


Figure 42.—Daily incoming solar radiation (direct and diffuse); annual regime. Langleys (gm-cal/cm²) received on a horizontal surface. Curves (and included data points) for Upper Columbia Snow Laboratory (UCSL) are based on 4-year period; three-station average based on 19 to 22 years at Great Falls, MT, Spokane, WA, and Suffield, AB.

sion to units of watthours/m², the numbers of langleys are multiplied by 0.0861.

On the actual mountain terrain, some large variations from the above amounts can be expected according to slope aspect and angle. The effects are greatest in winter. During December and January, a south-facing 30° (58 percent) slope may receive nearly twice as much total (direct and diffuse) radiation as a horizontal surface. A north-facing 30° slope may receive one-half the horizontal total and all of this will be diffuse radiation. These estimates incorporate direct radiation values presented by Buffo and others (1972). During July, the 30° south slope and horizontal surface should receive about the same total radiation; the north slope, perhaps 80 percent as much.

Evapotranspiration

Measurements from two standard evaporation pans adjacent to Glacier Park are summarized in table 13. The observed values integrate the effects of temperature, relative humidity, wind, and solar radiation. Also shown is the estimated potential evapotranspiration (PET) from soil and vegetation surfaces, derived by use of certain coefficients (Environmental Science Services Administration [ESSA] 1968). At both Hungry Horse Dam and Babb, on opposite sides of the park, the estimated PET is near 22 inches (560 mm) for the "warm season" (May-October) and 26 or 27 inches (about 675 mm) for the year. These amounts represent the combined evaporation and transpiration possible, given an adequate moisture supply at all times. Less PET can be expected on higher terrain as a result of the curtailing effect of lower temperatures and higher relative humidity. Because of the usual dry period during summer, the actual seasonal and annual evapotranspiration will be less than the potential.

Included in table 13 are PET totals calculated by the largely temperature-dependent Thornthwaite method (Thornthwaite and Mather 1957; Oliver 1973). These totals are lower than those just quoted and are apt to underestimate the true PET (Sellers 1965). The discrepancy is particularly large for annual totals, which are held down by the Thornthwaite method's assumption of no PET during months with mean temperatures of 32 °F (0 °C) or lower. Including three additional stations, Thornthwaite calculations give annual PET ranging from 15 inches (385 mm) at Summit to about 21.5 inches (545 mm) at Hungry Horse Dam and West Glacier.

Calculated annual "actual" evapotranspiration (AET), based on the Thornthwaite procedure, ranges from 14 inches (355 mm) at Summit and Polebridge to 18 inches (455 mm) at Hungry Horse Dam and West Glacier. (This is based on an adopted overall soil-moisture holding

Table 13.—Average (Avg.) monthly (warm-season) evaporation, inches, from "Class A" evaporation pans, observed during 1951-80. Also, estimated seasonal and annual potential evapotranspiration (PET), applying ratios or coefficients shown by ESSA (1968), and estimates (TAvg.) based on Thornthwaite method (see text)

Station		Pan evaporation								Est. PET	
		May	June	July	Aug.	Sept.	Oct.	May-Oct.		May-Oct.[1]	Year[2]
Babb 6NE	No. yrs	13	30	30	28	24					
	Average	5.95	6.20	7.16	5.97	4.19	—	31.47[3]	Avg.	22.66	26.98
	Std. dev.	0.92	1.06	1.00	.83	.77			TAvg.	18.45	19.14
Hungry Horse Dam	No. yrs	29	30	30	30	29	7				
	Average	4.93	5.72	7.88	6.71	3.33	1.43	30.00	Avg.	21.60	25.71
	Std. dev.	1.07	1.06	1.23	1.56	.72	.44		TAvg.	20.27	21.64

[1]Pan evaporation total multiplied by 0.72.
[2]May-October estimate divided by 0.84.
[3]Includes rough estimate of 2.00 inches for October.

capacity of 4 inches [100 mm] in the root zone.) True AET amounts may be about 2 or 3 inches greater.

Results from the Thornthwaite method are, nevertheless, used in figure 43 to portray the general changes in water balance during the year. The diagrams, plotted in conventional form, indicate the water surplus during much of the year at Summit (largely in snowpack storage and subsequent snowmelt). A normally slight deficit

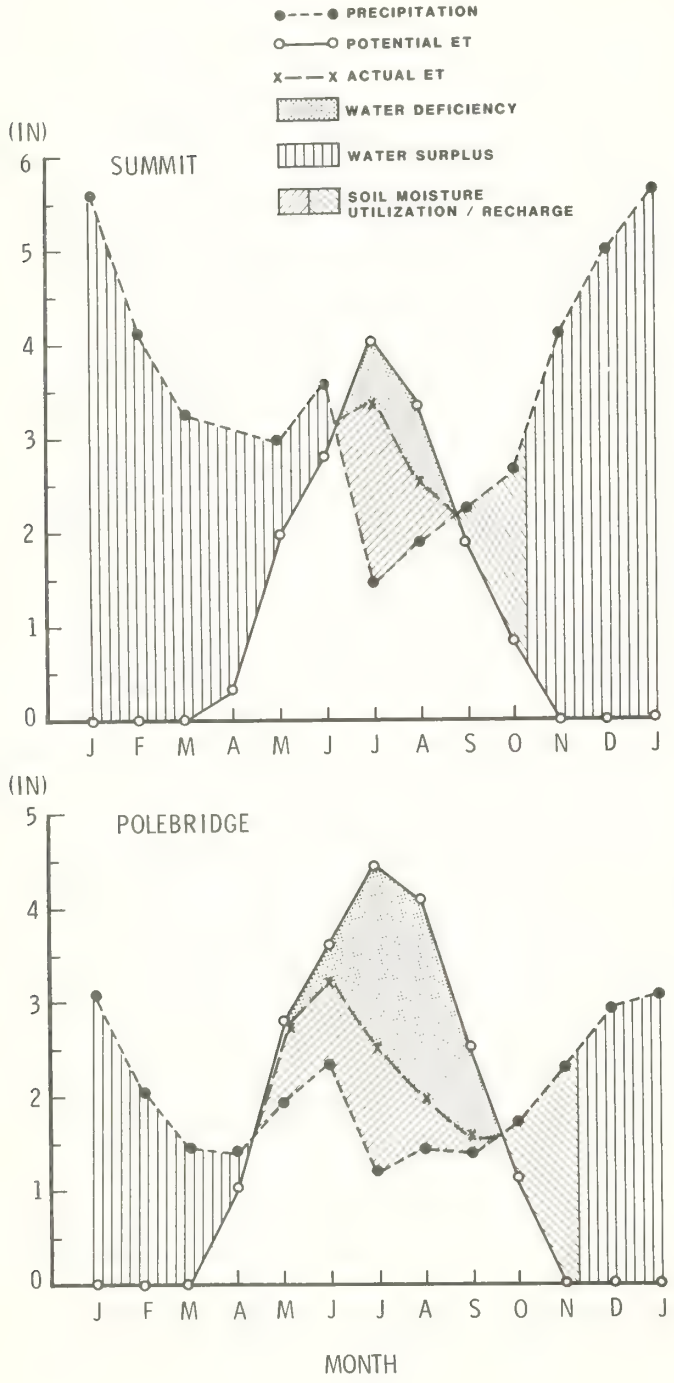


Figure 43.—Average water balance; schematic annual regime, based on the Thornthwaite method (see text) and 1951-80 monthly average temperature and precipitation.

period, with AET less than PET, appears during summer. A larger deficit, covering a longer season, is indicated at Polebridge. In individual years, severity of deficit—and, by implication, the fire danger—is seen to depend considerably on the vagaries of late spring and summertime precipitation.

Runoff

Figure 44 portrays the average annual (water-year) pattern of streamflow, as represented by the Middle Fork Flathead River—along the southwestern edge of Glacier Park. Over the period of a year and for the overall drainage area, this streamflow, or runoff, should equal the precipitation minus evapotranspiration. Also in the same figure is a three-station index of the precipitation, utilizing stations near the upper and lower ends of the drainage. The runoff shows considerable lag in its strong peak, from melting snowpack and spring rain precipitation, in May and June. These 2 months normally account for 59 percent of the yearly total runoff. A return to near base flow occurs in August, with a continuing decline to lowest levels in winter—when monthly runoff is 2 percent of total.

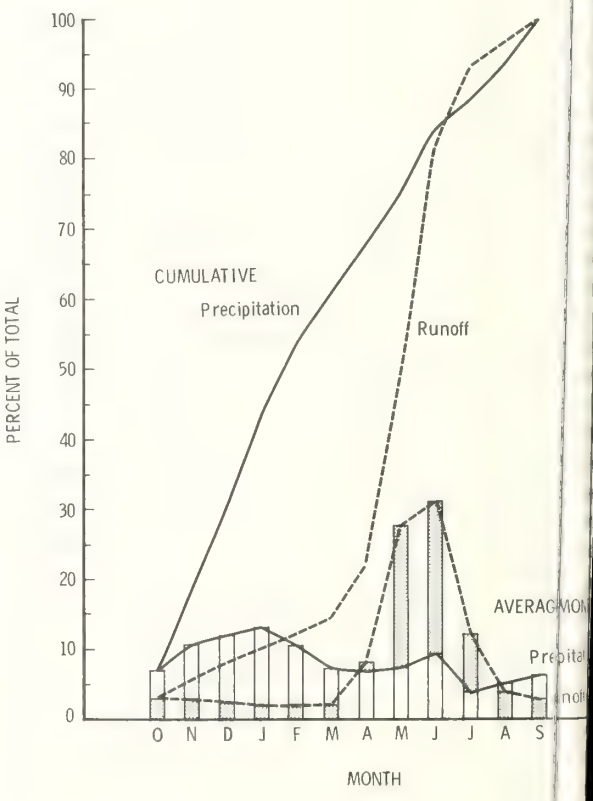


Figure 44.—Comparison of average water-year regimes of precipitation and runoff, southwestern portion of Glacier Park. Precipitation is three-station average from West Glacier, Essex, and Summit, based on or adjusted to 1951-80; runoff, that of Middle Fork Flathead River near West Glacier. Values, in percentage of yearly total, are adjusted to 30-day months.

able 14.—Monthly average runoff from drainages in Waterton-Glacier area, in percentage of annual total (see fig. 45); unregulated and undiverted streams. Based on 28 to 30 years during 1951-80 except as noted

rainage, area (mi²), auging point	**Oct.**	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**June**	**July**	**Aug.**	**Sept.**
	Percent											
iddle Fork Flathead River, 1,128, ıear West Glacier	3.1	2.8	2.5	2.0	1.9	2.2	7.8	28.1	30.6	12.1	4.1	2.8
'aterton River, 238, near Waterton Park	3.9	3.0	2.3	1.8	1.5	1.6	4.2	22.2	34.6	16.3	5.1	3.6
wiftcurrent Creek,[1] 31.4, at Many Glacier	5.3	3.4	2.0	1.6	1.3	1.5	4.6	21.7	29.5	16.4	7.2	5.4
rinnell Creek,[2] 3.47, near Many Glacier	5.0	2.5	1.2	1.0	.7	.8	2.9	15.5	28.4	22.2	12.7	7.2

[1]22 to 30 years of monthly data.
[2]26 to 28 years of monthly data.

The Middle Fork Flathead's yearly runoff has a moderely high correlation with a simple index of annual ecipitation, based on only two stations (Summit and est Glacier). For the 41 water years 1940-80, r was 7. Carryover of runoff from the preceding year is parently small, as indicated by a near-zero correlation tween successive yearly totals; r was 0.05.

The average runoff regime is generally similar in the ıer drainages, normally peaking during June; exam-es, table 14. (See figure 45 for drainage locations.) ta for Grinnell Creek show the relatively greater sum-rtime runoff proportion in an upper subdrainage area; s particular area includes Grinnell Glacier. Late sum-r icemelt and localized heavy showers may be con-buting factors here (Johnson 1980).

Annual runoff volumes for Waterton-Glacier drainages shown in figure 45. The numbers of acre-feet are, of ırse, largely dependent on drainage size. An average more than 2,200,000 acre-feet (272 000 ha-m) is ɔduced in the Middle Fork Flathead drainage (which ludes land outside the park); less than 500,000 acre-t (61 000 ha-m) in the much smaller Waterton River ainage. The areally averaged depth equivalents of the ıoff (calculated as: volume/drainage area) better reflect relative amounts of area-average precipitation. For ample, the 30-year average runoff depth over the ddle Fork Flathead, 37 inches (935 mm), indicates out 54 inches (1 370 mm) precipitation—assuming an erage of 17 inches (432 mm) evapotranspiration. The responding runoff depth is even larger, 39 inches 0 mm), over both the Waterton River and St. Mary ver drainages. This confirms earlier indications (fig. 9) ıt precipitation within Glacier Park can be as substan-l east of the Continental Divide as on the west side. ecipitation amounts do, of course, tend to decrease vard both the eastern and western edges of the park. Extremely high runoff depths are indicated in some odrainage areas close to the Divide, upward to 0 inches (2 540 mm) over the 3.47-mi² (9.0-km²) innell Creek drainage area. This amount corresponds th the Grinnell Glacier storage-gauge measurements of ecipitation (some of which may be snow blown into the

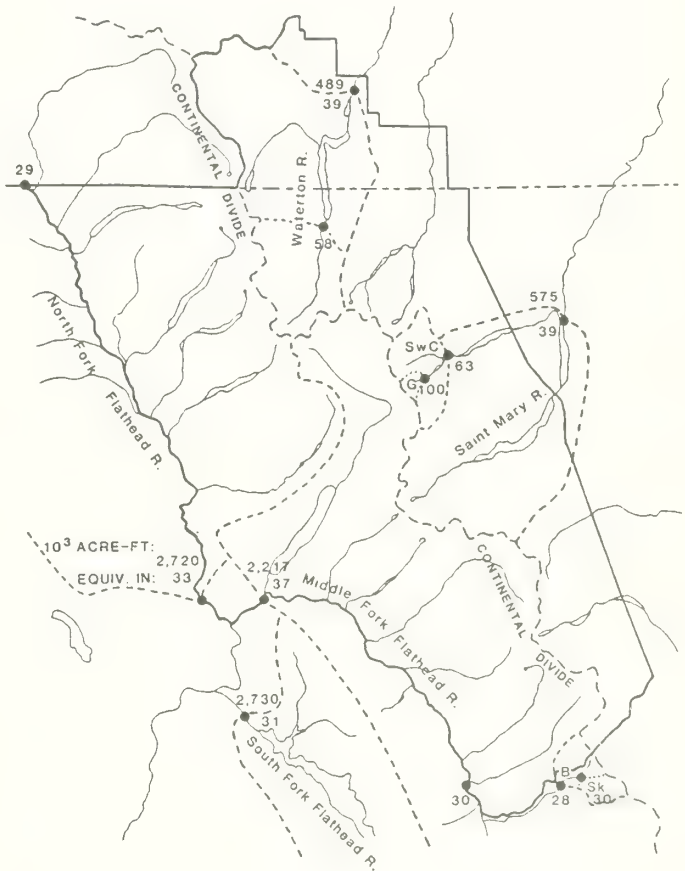


Figure 45.—Average yearly runoff, Waterton-Glacier Park area; based on or adjusted to period 1951-80. Values are given in thousands of acre-feet (top number) and equivalent areally averaged depth, inches (bottom or only number), for drainage area (outlined) above gauging point; values included for indicated subdrainages. G denotes Grinnell Creek; SwC, Swiftcurrent Creek (includes area of G); Sk, Skyland Creek; B, Bear Creek (includes area of Sk).

glacial cirque). Relatively low runoff depths shown for subdrainages comprising the UCSL study area, just west of the Divide, bear out the modest elevational increase in that area's observed precipitation (fig. 9).

Interdrainage correlation of annual runoff is found to be high, suggesting a high areal correlation of precipitation. For example, based on about 30 years, r was 0.90 between the Middle Fork Flathead River and the Waterton River; 0.91 between the Middle Fork Flathead and the St. Mary River; 0.97 between the St. Mary and the Waterton.

Highest streamflows on record, and probably during this century, are generally those associated with the June 7-8, 1964, storm and flooding ("Climatological Data," National summary for June 1964). A momentary peak flow of about 140,000 ft^3/sec (3 967 m^3/sec) occurred on the Middle Fork Flathead River near West Glacier—6.5 times the average peak for other years during 1951-70, including the previous record (since 1939) of 34,500 ft^3/sec (978 m^3/sec) in 1954. The Waterton River, near Waterton Park, reached 25,700 ft^3/sec (728 m^3/sec) and the St. Mary River, near Babb, 16,500 ft^3/sec (468 m^3/sec). These peaks exceeded levels recorded in 1908 and 1902, respectively.

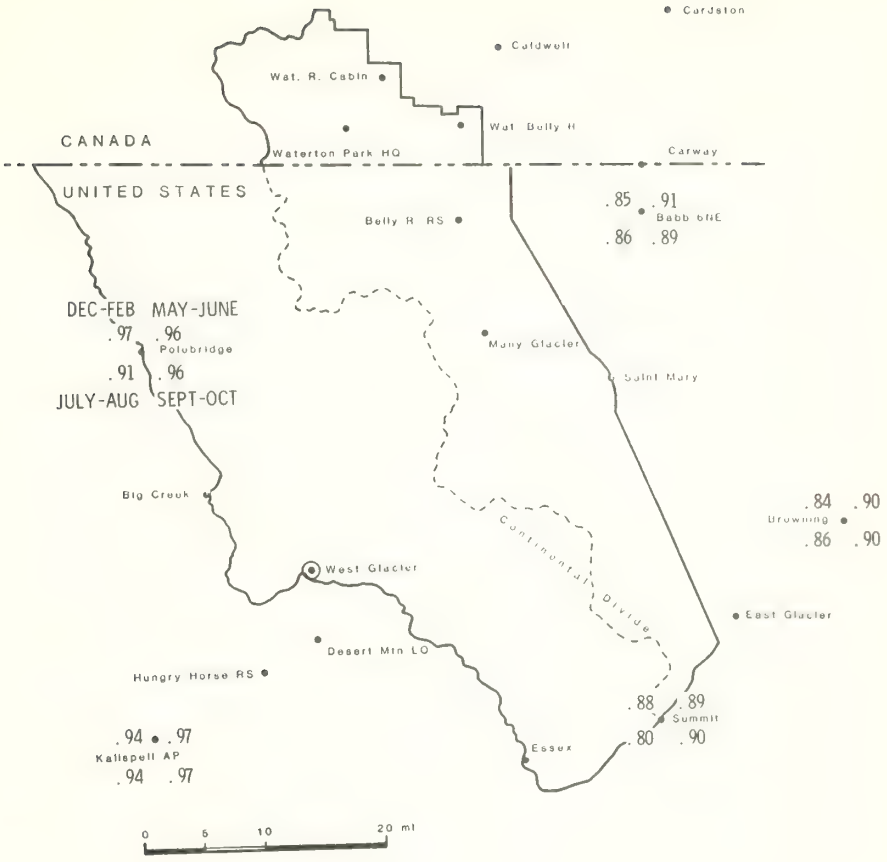
Weather Correlations Between Locations

As noted in previous sections, there is a general similarity across Glacier Park in the normal monthly trends (if not numerical values) of temperature, relative humidity, and precipitation. Perhaps of equal interest is the areal similarity, or correlation, in weather variations during individual years, on various time scales as small as 1 day. Such knowledge can be useful toward inferences between or beyond existing weather station locations; also toward estimates for missing station data.

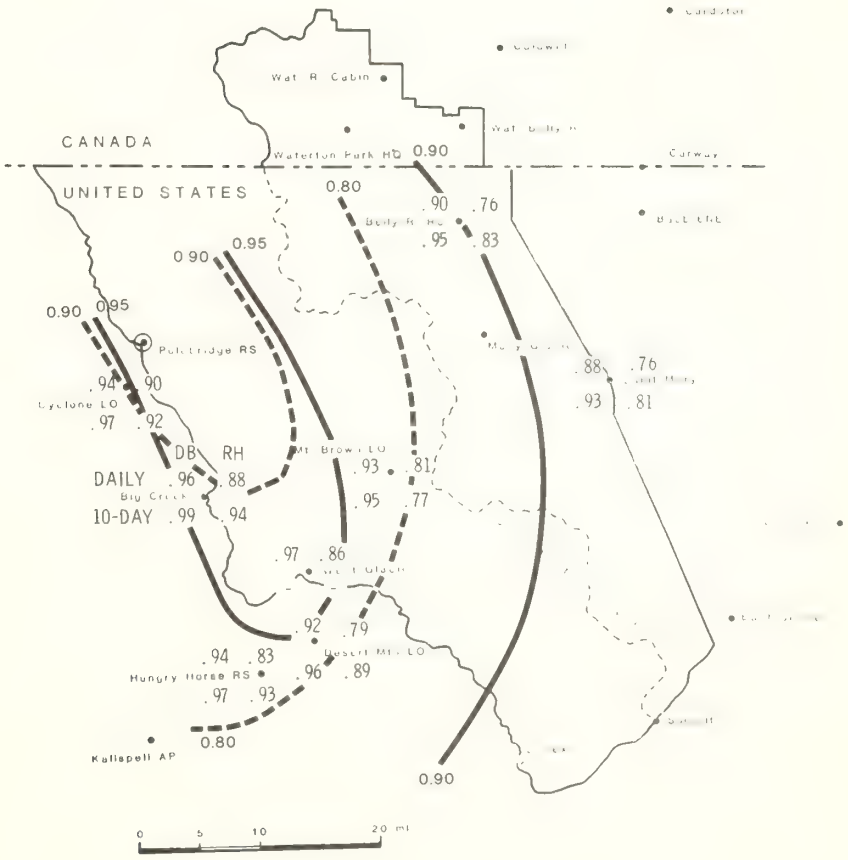
Some correlation results are shown in figures 46 through 49, using West Glacier as the reference station in all but the last figure. In this, for the needed length of fire-weather record, Polebridge R.S. serves as the reference.

Figures 46 and 47 reveal a generally high areal correl tion of afternoon or maximum temperatures. For all of the indicated time frames, correlation coefficients of 0.9 to 0.95 or better were obtained between west-side locations (and, not shown, also between east-side locations) values were nearly as high across opposite sides of the Continental Divide. Because of local or inversion-relate effects—varying with cloudiness and wind—correlation of minimum temperatures are generally lower, particularly in summer. For example, between West Glacier a Polebridge, r was 0.72 for July-August monthly averag minimums, compared with 0.91 for maximums. The December-February minimums, however, had a correla tion of 0.97, the same as for maximums. The correlatic of summer afternoon relative humidity (fig. 47) are sor what lower than those for temperature; some of this decline may result from humidity measurement errors.

Figure 48 indicates a moderately high correlation of monthly precipitation amounts between west-side locations, as does figure 49 for summertime 10-day amoun r was near or greater than 0.80. A similar correlation was obtained for the 10-day amounts on the east side, between Belly River and both St. Mary and East Glacier. The precipitation correlations between the we and east edges, however, are only about 0.50 to 0.60. Lower correlations occur on the 1-day (24-hour) time scale, but r was still near 0.80 between West Glacier a both Desert Mountain and Mount Brown.



gure 46.—Correlations of monthly average
aily maximum temperatures, between West
lacier and other stations; based on 1949-80
ata. Plotted numbers are averages of
dividual monthly correlation coefficients (r)
ouped by indicated seasons.



gure 47.—Correlations of summer after-
on dry bulb temperature (DB) and relative
midity (RH), daily and 10-day average,
tween Polebridge Ranger Station and
her stations; at 1600 m.s.t., July and
gust combined. Plotted daily coefficients
e based on available 1950-72 data, sampled
5-day intervals; 10-day based on 1946-72.
blines are drawn for daily values of r; solid
ne for DB and dashed line for RH.

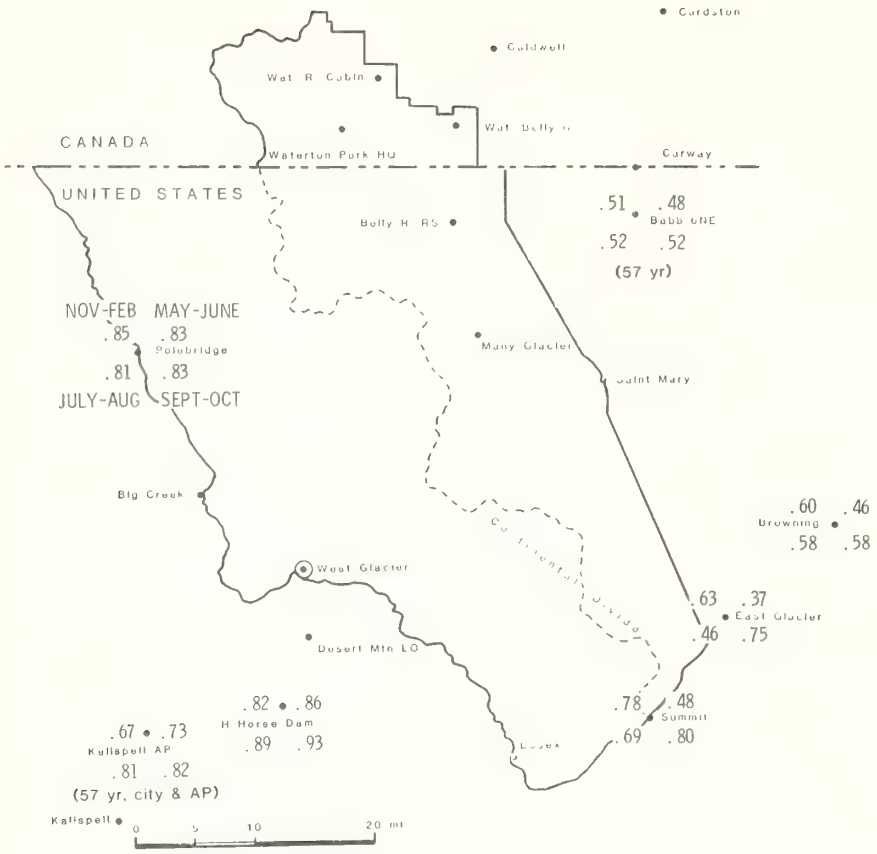


Figure 48.—Correlations of monthly precipitation totals between West Glacier and other stations; based on 32 to 37 years (through 1982) except as noted. Plotted numbers are averages of individual monthly correlation coefficients (r) grouped by indicated seasons.

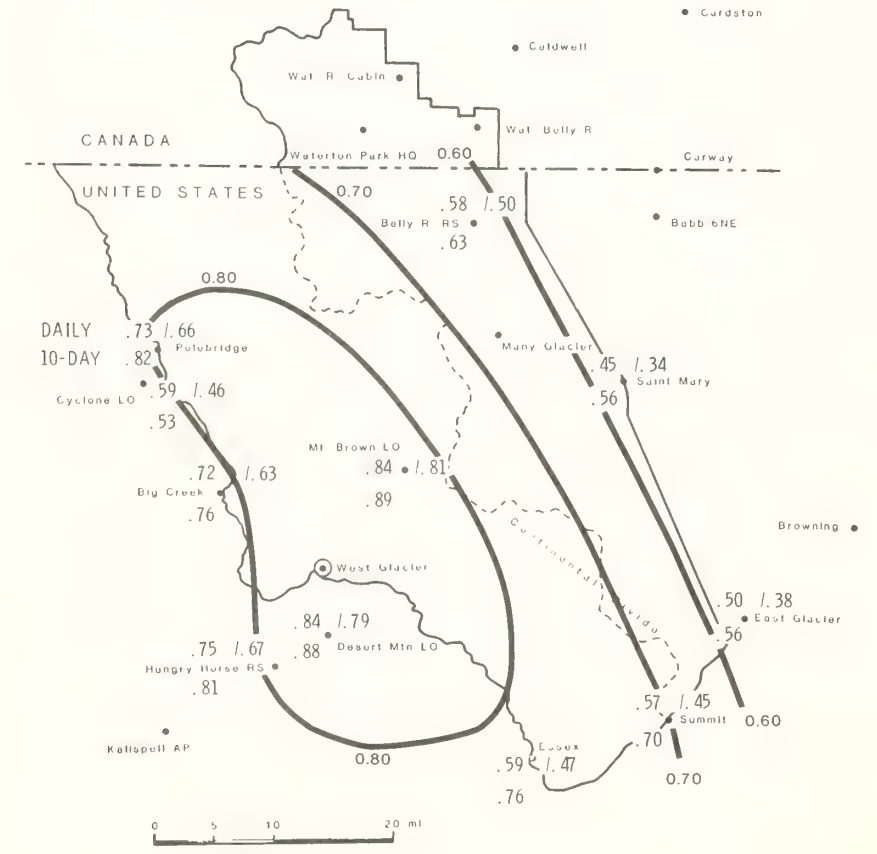


Figure 49.—Correlations of summertime precipitation, daily and 10-day, between West Glacier and other stations; based on available July and August 1946-72 data. Indicated daily coefficient (r) at left of slash is based on all days of record; value at right, on days with at least 0.01 inch at either station. Smooth lines are drawn for 10-day values of r.

Persistence of Weather

A tendency for persistence of the overall weather pattern from one month, season, or year to another could aid in fire management and other planning. Such persistence is examined here for temperature and precipitation, in terms of correlations—for a general indication—and frequencies or probabilities applicable to prediction. As with more elaborate methods of long-range forecasting, monthly or seasonal predictions based on persistence give only the gross outcomes relative to normal; important variations on smaller time scales may be obscured.

For temperature, specifically the average daily maximum, correlations were statistically significant between spring (May-June) and summer (July-August) averages, mostly at the 1 percent level (Freese 1967; Snedecor 1956). The correlation coefficients, obtained at six stations and based on 27 to 32 years (1949-80), ranged from 0.36 to 0.51. (Daily maximum, rather than the 24-hour mean temperature, was chosen as better relating to the clear, dry—or cloudy, moist—character of the 2-month periods.) Temperature correlations between the individual months and also between other pairs of seasons were poorer. For example, at West Glacier during 1931-83, r was −0.03 between the May and June average maximums, 0.04 between June and July, and 0.17 between July and August—compared with 0.45 between May-June and July-August.

The spring and summer temperatures are compared further, by class frequencies, in table 15 (example for West Glacier). In the 53-year (1931-83) data sample, a defined warmer than normal May-June was followed by a warmer than normal July-August in 53 percent of the (15) cases, a cool July-August in 13 percent. Nearly the converse tendency is shown following a cooler than normal May-June. A chi-square test (Freese 1967; Snedecor 1956) does barely indicate, by conventional standards, a statistically significant persistence in table 15 (P, 0.05).

Table 16, for precipitation at West Glacier, suggests a persistence tendency following both a wetter than normal and a drier than normal May-June. In the 52-year sample, there was a twofold or threefold frequency of an identical July-August precipitation class as compared with an opposite class. Nevertheless, a chi-square test gives no statistical significance here (P was about 0.25).

Correlations between the actual amounts of May-June and July-August precipitation, at seven stations, were all very low (r ranged from −0.08 to 0.19). They were similarly low between other seasonal totals, between successive monthly totals (from May to October), and between annual totals.

Table 15.—Frequency of specified maximum-temperature classes[1] in summer (July-August) following those in spring (May-June); at West Glacier, MT, based on 53 years 1931-83. For each combination of May-June and July-August classes, listed top number is the actual number of cases; bottom number is the percentage of all cases in the corresponding row

May-June max. temp. class	July-August max. temp. class: Below normal	Near normal	Above normal	Total cases	Chi-square test value
	-- Number of cases --				
Below normal	8	6	1	15	
	Percent of total in row				
	53	40	7		
Near normal	8	9	6	23	
	35	39	26		
Above normal	2	5	8	15	
	13	33	53		
Total cases	18	20	15	53	[2]9.49

[1]Criteria are based on standard deviation (SD) about the 53-year average maximum value; SD was taken as 2.6 °F (average of 2.3 °F observed for May-June and 2.8 °F for July-August). "Above normal" class is defined as temperature > +0.5 SD (1.3 °F) from average; "near normal," within ±0.5 SD of average; "below normal," < −0.5 SD from average.
[2]Statistically significant; P = 0.05.

Table 16.—Frequency of specified precipitation classes[1] in summer (July-August) following those in spring (May-June); at West Glacier, MT, based on 52 years 1931-82. Numbers listed as in table 15

May-June precip. class	July-August precipitation class: Below normal	Near normal	Above normal	Total cases	Chi-square test value
	----- Number of cases -----				
Below normal	6	7	2	15	
	Percent of total in row				
	40	47	13		
Near normal	5	4	9	18	
	28	22	50		
Above normal	4	7	8	19	
	21	37	42		
Total cases	15	18	19	52	[2]5.77

[1]Criteria are based on percentage of 52-year average 2-month precipitation totals and also consider the median totals and variability. Defined "near normal" limits are 85-110 percent for May-June; 75-120 percent for July-August.
[2]Not statistically significant; P about 0.25.

Climatic Trends

The various averages and frequencies that have been presented apply to a basically stable climatic state. These statistics integrate the variations or differences in weather that can be expected between individual years or series of years. A sequence of years with abnormal conditions may, nevertheless, lead to impressions of a climatic cycle, if not a changing climate. Whatever their regularity or significance, such cycles are found to be fluctuations superimposed upon longer cycles or trends—on the scale of hundreds or thousands of years and including ice ages (Oliver 1973; Critchfield 1974; Hare and Thomas 1974; National Research Council 1975).

Figures 50 and 51 chart the climatic trends or fluctuations of observed precipitation and temperature, respectively, in or near Glacier Park; data are limited to this century. The graphs employ two forms of smoothing—by 11-year running means and 5-year weighted means, both representing overlapping sequences of years. The first

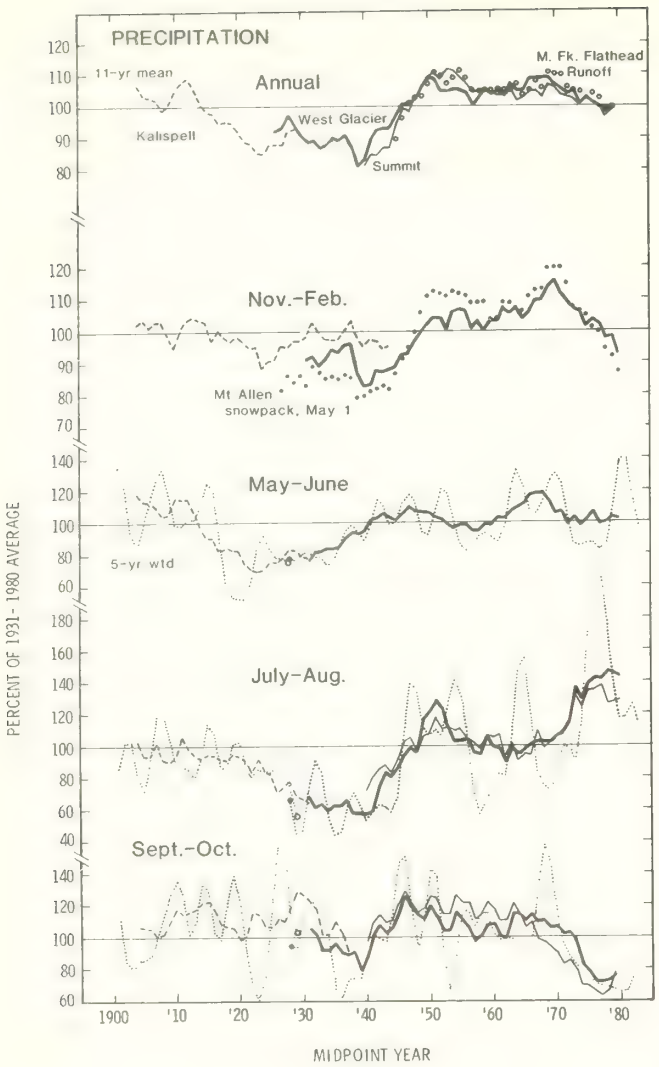


Figure 50.—Trends or fluctuations of annual and seasonal precipitation (or precipitation indexes) during this century; Glacier Park area, near or west of Continental Divide. Based on data through August 1985. Shown by 11-year and 5-year (weighted) running means (see text), plotted at midpoint years, in percentage of observed or estimated 1931-80 average. Small open circles near 1930 denote ending of plotted 5-year graph based on Kalispell; filled circles, beginning of West Glacier segment—some overlap is included for comparison.

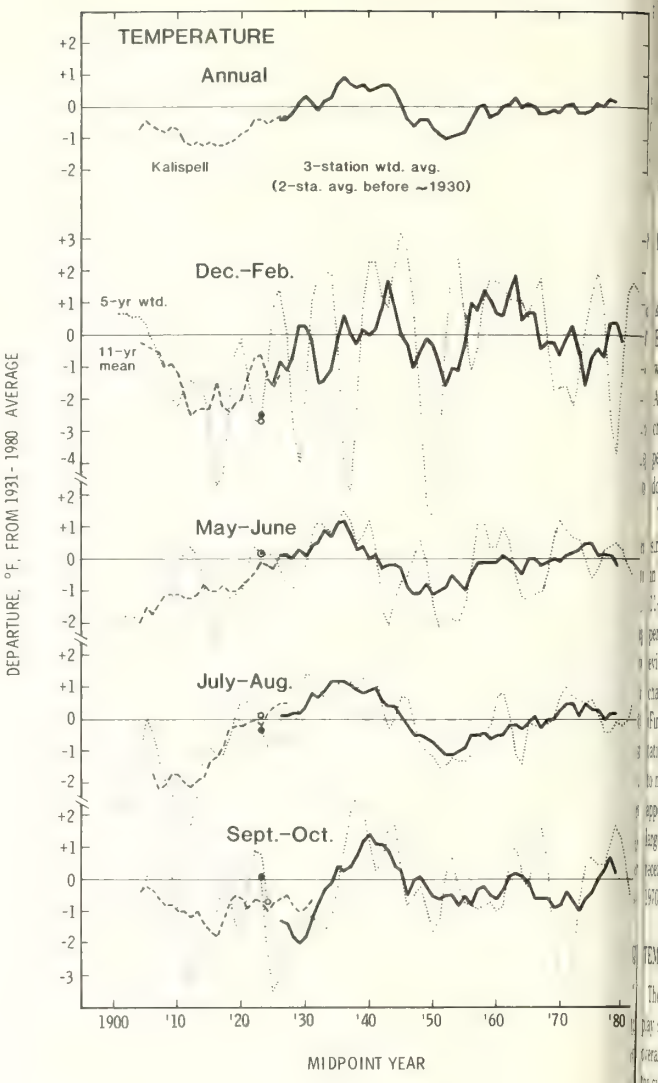


Figure 51.—Trends or fluctuations of annual and seasonal mean temperatures (averages of daily maximum and minimum); Glacier Park area, west and east of Continental Divide. Based on data through February 1985. Shown as in figure 50, except plotted values are degree departures from calculated 1931-80 average. "Three-station" average is based on Kalispell, West Glacier, and Babb 6NE (given two weights); Kalispell data are from airport station after 1950 (1931-80 baseline was adjusted accordingly).

form gives equal weighting to each year's data; use of 11 years, rather than 10, allows easier placement of a midpoint. The second form, portraying short-term fluctuations, applies successive weighting of 1, 4, 6, 4, and 1; this "binomial" filter is described further by Panofsky and Brier (1963). Resulting values are plotted relative to the recent 50-year, 1931-80 average.

PRECIPITATION

The broader features of figure 50 include the well-known dry period centered in the 1920's and 1930's. Eleven-year mean annual precipitation at West Glacier was as low as 81 percent of the 1931-80 average; July-August, 58 percent. The annual means show little overall change following a recovery by 1950, to as high as 109 percent, but the recent trend has been generally downward.

The seasonal graphs display some opposing tendencies since the recovery around 1950. Notable is the increase in July-August precipitation during the 1970's. The 11-year and 5-year (weighted) means, reaching about 140 percent and 200 percent of average, respectively, were evidently at their highest levels of the century. This characteristic was likewise found at Priest River, ID (Finklin 1983b). In contrast, September-October precipitation has been exceptionally low in recent years, prior to much higher amounts in 1984 and 1985 (table 20, appendix). November-February amounts, contributing a large portion of the annual precipitation, also show a recent decline—following a strong peak centered around 1970.

TEMPERATURE

The annual and seasonal graphs in figure 51 again display some opposing fluctuations, but they share in an overall warming trend during the 1910's and 1920's and the subsequent peak values in the 1930's or early 1940's—coinciding with the low precipitation. They show subsequent cooling until around 1950 to 1955. During this course the 11-year annual means, based on a three-station index, reached 0.9 °F (0.5 °C) above, and then 1.0 °F (0.6 °C) below, the 1931-80 average. These means were up to the long-term average value by the late 1950's and since then have fluctuated very little.

The late spring and summer temperatures show a continued, overall rise since the 1950-55 values, though a slight downward fluctuation to near average has occurred recently. Wide fluctuations characterize the winter graphs. Since about 1910, latest 11-year means indicate a net warming of 2 °F in both winter and summer and 1 °F for the year.

This warming follows the overall global and northern hemispheric trends (above references and National Research Council 1983), though many of the details differ. Some of the fluctuations are out of phase with those in eastern parts of the United States and Canada (Diaz and Quayle 1980; Hare and Thomas 1974). This difference appears related to the prevailing upper-air trough and ridge positions—their east-west spacing and shifts in location. The fluctuations also show some differences with those averaged over the entire northern and central Rocky Mountain area (Bradley 1980); the use of differently defined seasons may be a contributing factor.

Authorities disagree as to the role of the much-publicized carbon dioxide (CO_2) "greenhouse effect" in this century's warming to date (National Research Council [NRC] 1983; Yulsman 1984), though the consensus expects a more definite effect in the future. A conservative projection by the NRC calls for an additional global average warming of about 3 °C (5 °F)—from a doubling of atmospheric CO_2 due to fossil fuel burning—by the year 2075, with greater warming at high latitudes. The Environmental Protection Agency (EPA) predicts such a change by 2050. Should this change occur, the higher average temperatures impacting Waterton-Glacier would apparently exceed those during the postglacial warm period around 5,000 to 7,000 years ago (National Research Council 1975).

SUMMARY

As shown by the various data, the Glacier Park area has climatic characteristics generally identified with mountainous terrain; these are superimposed upon the broader climate associated with geographic location. Some large differences in precipitation amounts and average temperatures are found within the 1,583-mi^2 (4 100-km^2) park area, but the normal annual regimes of these and other climatic elements are generally similar or parallel. An exception occurs with respect to wind.

Thus, though normal annual precipitation may range from 23 inches (585 mm) to 100 inches (2 500 mm) or more, winter (particularly November-January) is the wettest, or snowiest, time of year over most of the park. Likewise, this area generally has a secondary precipitation peak in late spring (May-June) and a minimum in summer (July-August). The pattern changes—with much less winter precipitation—on the plains immediately east and in the main Flathead Valley to the west of Glacier Park. Average windspeeds, in contrast, show rather diverse annual regimes—with topography and location east or west of the Continental Divide dominant factors. Winter is the windiest time of year east of the Divide and on exposed mountain terrain, in line with the free-air wind conditions. Average speeds are then near a minimum in western valley locations.

Though large contrasts can occur across the Continental Divide on individual days, afternoon (or maximum) temperatures during summer and the other seasons show a strong areal correlation (between stations, the coefficient r was commonly 0.90 to 0.95). This applies to daily as well as monthly-average maximum temperatures. The correlation of afternoon relative humidity (observed during summer) is somewhat lower though still high. Correlation of precipitation amounts, on daily to monthly time scales, is moderately high ($r \sim 0.75$ to 0.85) within distances of about 25 mi (40 km).

In an examination of weather persistence, based on 53 years at West Glacier, a statistically significant relationship was indicated between average maximum temperatures during late spring and the ensuing summer. Predictive ability, however, involves only the gross 2-month outcomes relative to normal. As an example, a defined warmer than normal May-June was followed by a warmer than normal July-August in 53 percent of the

(15) cases; a cool July-August, in 13 percent; near normal July-August, in 33 percent. Practically no persistence or correlation was found between the successive individual monthly temperature values—between those in May and June, June and July, or July and August. A persistence tendency between May-June and July-August precipitation was not statistically significant.

Climatic trends or fluctuations during this century were examined by use of 11-year and 5-year (weighted) running means. Summer (July-August) temperatures show an overall warming of 2 °F since the 1910's, though the highest sustained averages to date were centered in the dry 1930's. A notable increase in July-August precipitation has occurred since 1974, followed by a most recent decline. In contrast, autumn (September-October) was exceptionally dry during recent years (but rather wet in 1984 and 1985). At fire-weather stations, July-August afternoon relative humidity observed during 1974-83 averaged about 10 percent higher than for 1951-70. This appears to reflect a more moist, unrepresentative summertime regime, but up to one-half of the difference may be attributed to a change in observation time initiated in 1974—from 1600 to 1300 m.s.t. The present observation time does not as well represent the afternoon extreme conditions in this area.

Various tables and graphs are presented as an aid in fire management planning; these summarize data for valley and 6,000-ft (1 830-m) locations. An important feature of the Glacier Park area is the much greater occurrence of wildfire west of the Divide—where about 90 percent of the reported natural (lightning-caused) fires have burned. (There is a slight bias, as the west side contains 60 percent of the park's land area.) Climatic findings in this report do not support some published explanations for the difference in fire—and for the basic difference in vegetation (and fuel loading and continuity); these differences are sometimes attributed to less precipitation and lightning activity on the east side. The lesser timber here may indicate less available moisture, but our data suggest that precipitation and its monthly distribution are generally similar to that on the west side. Instead, wintertime dessication may have a significant effect on the east-side conifers; this is a result of chinook winds and related large, rapid temperature changes (Arno and Hammerly 1984).

In addition, examination of a Glacier Park topographic map, with superimposed green color, suggests that the rugged, rocky terrain greatly limits the extent and continuity of forests east of the Divide. Potential prairie-type fuels, near the eastern edge, are heavily grazed by wildlife.

Nevertheless, more fire starts might be expected on the east side than actually occur—even if these fires remain small. Our data indicate that lightning activity is as frequent here as on the west side. More of the east-side lightning discharges, however, between cloud and ground, may be favored on higher, largely barren terrain. Fuel moisture during the summer would certainly be a suspected ignition factor, though a more definitive explanation requires further study. Peterson (1971) examined the lightning-fire contrast over a broader area—between the eastern and western fire-weather zones of the Forest Service Northern Region. He noted the difference in how light, flashy fuels and heavy fuels respond to the increased relative humidity and the rainfall accompanying summer thunderstorms. In such a case the generally lighter, faster responding fuels on th east side of Glacier might not ignite easily.

Though this report has presented many climatic details, there are inevitably large gaps in the data coverage—in dimensions of both space and time. To some extent, inferences can be made from the high corr lations between stations and from the general relationships shown with topography, particularly elevation. Fo more site-specific data needs, the available averages ca serve as a starting point from which local differences may be determined by field observations. The local effects should be at a maximum during fair, quiet weather situations. Additional stations would certainly be welcome, though there would never be enough to reveal all that a manager or researcher might wish to know. One recommended location for an additional fire-weather station is in the far southern portion of Glacie Park—in the Middle Fork Flathead River drainage. A promising future source of data, on an hourly basis, is the Remote Automatic Weather Station (RAWS) now employed by other Federal agencies in the Northern Rockies.

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APPENDIX: TABLES 17-36

Table 17.--Differences in monthly average temperatures, °F, due to observation days ending at differing times, 5 p.m. and 12 midnight, m.s.t., at two stations in Glacier Park-western Montana area. Based on hygrothermograph readings at Upper Columbia Snow Laboratory (UCSL), 1947-50, and near Missoula, 1967-72

Station		5 p.m.-5 p.m. average minus midnight-midnight average[1]												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		- °F -												
UCSL Hqtrs.	Max.	+0.7	+0.8	+1.2	+1.4	+1.6	+1.6	+1.6	+2.0	+2.0	+1.0	+0.4	+0.4	+1.2
(Sta. 1B)	Min.	+1.6	+1.3	+1.5	+1.2	+ .8	+ .7	+ .6	+ .9	+1.2	+1.0	+1.1	+1.5	+1.1
	Mean	+1.2	+1.1	+1.4	+1.3	+1.2	+1.2	+1.1	+1.5	+1.6	+1.0	+ .8	+1.0	+1.2
Missoula 2NE	Max.	+ .6	+ .9	+1.2	+1.6	+1.8	+1.9	+1.7	+1.7	+1.8	+1.1	+ .7	+ .6	+1.3
	Min.	+1.0	+ .8	+ .8	+ .9	+ .6	+ .7	+ .6	+ .6	+ .9	+1.0	+1.1	+1.1	+ .8
	Mean	+ .8	+ .9	+1.0	+1.3	+1.2	+1.3	+1.2	+1.2	+1.4	+1.1	+ .9	+ .9	+1.1

[1] Original average differences smoothed by 1-4-1 weighting applied to successive monthly values.

able 18.--Climatological summaries for West Glacier, Polebridge, and Summit, MT; based on 24-hour periods ending at indicated observation times (m.s.t.). Averages based on 1951-80 for temperature and 1941-80 for precipitation and snowfall, except as noted. Average number of days, 1949-78. Extremes for 1931-1985, except as noted. T denotes trace, and amount too small to measure; + denotes occurrence also in earlier years; * denotes less than one-half

est Glacier - Lat. 48° 30', Long. 113° 59'; Elevation 3,180 ft (corrected). Observation time 5 p.m.

Summary information	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
EMPERATURE, °F													
Averages:													
Daily maximum	27.6	34.8	41.0	52.1	63.7	70.9	79.6	77.6	66.4	52.9	37.5	30.8	52.9
Daily minimum	13.4	18.9	21.6	29.1	36.5	43.2	46.6	45.8	38.8	31.7	24.4	19.0	30.7
Monthly	20.5	26.9	31.3	40.6	50.1	57.1	63.1	61.7	52.6	42.3	31.0	25.0	41.8
Extremes:													
Highest	52	58	64	80	91	92	101	99	94	79	67	54	101
Year	1931	1950	1941	1939	1936	1941+	1934	1969	1967	1942	1948	1941	1934
Lowest	-37	-40	-30	-8	13	24	31	31	16	-9	-29	-36	-40
Year	1937	1933	1960	1936+	1954	1959	1979	1937	1934	1936	1959	1968	1933
RECIPITATION													
OTAL, INCHES													
Average	3.35	2.47	1.78	1.81	2.55	3.28	1.56	1.73	2.11	2.43	3.05	3.40	29.52
Highest													
monthly	7.07	5.87	4.43	4.50	4.94	6.83	4.70	5.14	6.17	5.96	7.52	7.72	7.72
Year	1953	1940	1932	1948	1968	1981	1983	1954	1968	1933	1959	1980	1980 Dec.
Lowest													
monthly	.16	.21	.47	.27	.76	.75	.00	.00	.35	.08	.27	.81	.00
Year	1985	1934	1965	1952	1947	1977	1960	1955	1957	1952	1936	1985	1960+ July
Highest													
daily	1.43	2.09	.95	1.41	1.64	3.47	1.68	2.08	1.59	1.76	1.50	2.38	3.47
Year	1971	1951	1947	1974	1980	1964	1964	1947	1952	1955	1932	1964	1964 June
Snowfall													
Average	40.0	24.3	15.8	4.0	.6	.3	.00	.00	.2	2.0	17.5	34.2	138.9
Highest													
monthly	93.0	57.5	50.4	24.0	5.0	8.0	.00	.00	3.5	28.0	58.3	95.0	95.0 Dec.
Year	1972	1937	1964	1948	1964+	1966			1972	1951	1959	1971	1971
Highest													
daily	19.0	16.0	15.0	8.5	5.0	8.0	.00	.00	3.0	12.0	12.0	20.0	20.0
Year	1972+	1957	1954	1953	1951	1966			1965	1951	1959+	1938	1938 Dec.
ERAGE NUMBER													
DAYS													
recipitation													
>0.10 inch	11	7	7	6	7	7	4	5	6	7	9	11	87
nowfall													
≥1.0 inch	13	8	6	1	*	*	0	0	*	1	4	12	44
emperature, °F													
Max. >90	0	0	0	0	0	*	2	2	*	0	0	0	4
Max. ≤32	18	8	4	*	0	0	0	0	0	*	7	16	53
Min. ≤32	30	27	29	22	9	1	*	*	6	18	26	30	198
Min. ≤0	6	2	1	0	0	0	0	0	0	0	1	2	12

(con.)

Table 18. (Con.)

Polebridge - Lat. 48° 46', Long. 114° 16'; Elevation 3,520 ft. Observation time 5 p.m.; 7 a.m. beginning April 1975

Summary information	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ye
TEMPERATURE, °F[1]													
Averages:													
Daily maximum	27.4	36.2	41.7	52.3	63.5	71.1	80.2	78.8	68.7	54.8	37.9	30.4	5
Daily minimum	6.8	12.7	16.2	25.2	32.1	38.5	40.8	39.1	33.0	25.9	18.9	12.3	2
Monthly	17.1	24.5	29.0	38.8	47.8	54.8	60.5	59.0	50.9	40.4	28.4	21.4	3
Extremes:													
Highest	51	58	65	86	92	96	101	102	99	85	65	53	
Year	1962	1963	1978	1936	1936	1937	1934	1969	1967	1955	1981	1980	1
Lowest	-46	-45	-38	-12	-5	21	25	25	5	-21	-38	-43	
Year	1957	1936	1960	1936	1954	1951	1979	1937	1934	1936	1959	1978	1
PRECIPITATION[2]													
TOTAL, INCHES													
Average	2.80	1.95	1.50	1.33	1.91	2.32	1.26	1.41	1.34	1.75	2.36	2.69	22
Highest													
monthly	6.92	4.38	2.98	3.39	3.83	5.50	3.74	4.81	4.45	4.37	6.08	5.69	6
Year	1954	1949	1934	1954	1980	1966	1948	1954	1959	1967	1973	1980	1 J
Lowest													
monthly	.05	.17	.49	.36	.29	.54	T	.00	.09	.07	.05	.48	
Year	1985	1935	1978	1947	1983	1961	1967	1969	1967+	1952	1936	1985	1 A
Highest													
daily	1.53	1.10	1.50	1.10	1.73	2.43	1.33	1.34	1.03	1.50	1.56	1.27	2
Year	1953	1961	1954	1974	1959	1966	1948	1954	1959	1934	1946	1964	1 J
Snowfall													
Average	34.6	20.8	13.1	3.8	.7	.4	.0	.0	.4	3.3	16.2	26.9	12
Highest													
monthly	91.2	59.7	44.9	24.8	8.7	8.3	.0	.0	6.0	17.0	53.2	68.7	9
Year	1954	1937	1964	1954	1956	1966			1949	1975	1946	1971	1 J
Highest													
daily	20.0	15.0	16.0	9.0	6.0	8.3	.0	.0	4.0	8.0	16.5	17.0	2
Year	1954	1975	1954	1951	1956	1966			1937	1949	1958	1961	1 J
AVERAGE NUMBER OF DAYS													
Precipitation													
≥0.10 inch	10	6	5	5	6	6	4	4	5	6	7	9	
Snowfall													
≥1.0 inch	10	6	5	2	*	*	0	0	*	1	5	8	
Temperature, °F													
Max. >90	0	0	0	0	0	*	3	4	1	0	0	0	
Max. ≤32	18	7	3	*	0	0	0	0	0	*	7	16	
Min. ≤32	30	28	30	25	17	6	2	4	15	24	28	30	
Min. ≤0	10	5	4	*	*	0	0	0	*	*	2	6	

(con

Table 18. (Con.)

Summit[3] - Lat. 48° 19', Long. 113° 21'; Elevation 5,215 ft. Observation time mostly about 5 p.m.

Summary Information	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
TEMPERATURE, °F[4]													
Daily maximum	22.7	29.6	33.7	44.1	55.2	63.7	72.6	70.9	60.3	48.5	33.1	26.5	46.7
Daily minimum	6.5	13.0	14.4	23.2	30.6	37.3	41.0	39.9	34.3	28.6	18.8	12.6	25.0
Monthly	14.6	21.3	24.1	33.7	42.9	50.5	56.8	55.4	47.3	38.6	26.0	19.6	35.9
Extremes:													
Highest	48	56	62	74	81	90	93	96	92	82	64	57	96
Year	1968+	1958	1960	1977+	1936	1936	1960	1969+	1967	1957	1975	1939	1969+
Lowest	-55	-43	-42	-30	2	15	22	19	6	-30	-42	-46	-55
Year	1959	1962	1960	1940+	1967	1951	1971	1939	1957	1935	1959	1968	1959
PRECIPITATION TOTAL, INCHES													
Average	5.13	3.88	3.20	2.82	3.02	3.80	1.40	1.82	2.34	2.82	4.21	4.80	39.24
Highest													
Monthly	14.00	8.52	7.03	6.21	7.15	9.58	3.69	4.28	7.10	7.53	8.21	8.73	14.00
Year	1953	1979	1974	1970	1964	1975	1972	1977	1985	1950	1958	1949	1953 Jan.
Lowest													
Monthly	.20	.59	.98	.60	1.12	.27	.03	.00	.20	.34[5]	.64	.95	.00
Year	1985	1935	1941	1944	1947	1961	1973	1955	1966	1953	1936	1935	1955 Aug.
Highest													
Daily	2.95	2.50	1.45	1.96	2.55	7.31	1.55	2.00	1.60	1.55	2.35	2.25	7.31
Year	1953	1961	1945	1951	1964	1964	1972	1972	1940	1951	1978	1968	1964 June
Snowfall													
Average	52.6	40.2	34.4	24.0	8.6	1.4	.1	T	5.3	12.8	36.2	45.1	260.7
Highest													
Monthly	131.1	94.5	72.7	87.0	28.5	16.5	4.0	.5	29.0[6]	61.0	76.9	94.1	131.1
Year	1972	1976	1956	1954	1938	1943	1972	1952	1961	1951	1946	1949	1972 Jan.
Highest													
Daily	44.0	20.5	26.5	19.0	18.0[7]	16.5	4.0	.5	12.0	30.0	23.0	18.5	44.0
Year	1972	1970	1947	1974	1964	1943	1972	1952	1965	1951	1958	1938	1972 Jan.
AVERAGE NUMBER OF DAYS													
Precipitation													
).10 inch	15	12	11	9	8	8	5	5	6	9	11	14	113
Snowfall													
1.0 inch	15	11	11	7	3	*	*	0	1	4	10	14	76
Temperature, °F													
ax. >90	0	0	0	0	0	0	*	*	*	0	0	0	*
ax. ≤32	24	16	13	3	1	0	0	0	*	2	13	21	93
in. ≤32	30	28	30	27	20	7	4	5	14	20	26	30	241
in. ≤0	11	5	5	1	0	0	0	0	0	*	3	6	31

[1]Temperature data missing 1939-45.
[2]Precipitation data missing 1939-41; snowfall missing 1939-44.
[3]Record begins in 1935; ends April 1979, except for precipitation. Fischer-Porter recording gauge beginning May 1979.
[4]Adjusted to complete 30 years, 1951-80.
[5]Originally published monthly total corrected, based on recording gauge data.
[6]Includes estimate of 4.0 inches for missing daily amounts.
[7]24-hour increase in reported snow depth; snowfall data missing.

Table 19.--Monthly average precipitation (P) and snowfall (S), based on or adjusted to 30-year normal period, 1951-80. Stations in Montana except as noted in Alberta (AB).[1]

Station		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		Inches												
Babb 6NE	P	0.94	0.88	0.86	1.52	2.76	3.69	1.58	2.10	1.88	0.87	0.75	0.90	18.71
	S													~100
Browning	P[2]	1.13	0.84	0.81	1.38	2.04	2.87	1.48	1.57	1.13	0.72	0.76	0.78	15.51
	S[2]	15.5	12.0	9.0	9.5	1.5	0.5			1.8	3.5	8.5	10.2	72.0
Carway, AB	P	1.26	1.32	1.40	1.93	2.68	3.52	1.44	1.87	1.71	0.87	1.06	1.22	20.29
	S	12.2	13.1	13.7	16.2	5.7	1.4	T	0.1	5.2	6.7	9.9	12.0	96.2
East Glacier	P	3.97	2.76	2.36	2.39	2.62	3.25	1.41	1.76	1.88	1.84	2.99	3.27	30.50
	S	39.3	32.8	26.6	20.2	4.4	0.4		T	2.6	8.4	26.6	32.9	194.2
Essex	P	5.52	4.05	2.92	2.65	2.80	3.30	1.52	1.95	2.63	3.00	4.50	5.10	39.94
	S	58.0	38.0	21.0	11.0	3.0	0.3			1.0	5.5	27.0	45.0	209.8
Flattop Mtn.	P[3]	10.95	8.03	7.45	5.77	5.15	5.90	2.55	2.90	3.90	5.50	9.25	11.03	78.38
Hungry Horse Dam	P	3.83	2.66	2.20	2.13	2.74	3.19	1.61	2.20	2.56	3.00	3.56	3.82	33.50
Kalispell AP	P	1.62	1.06	0.84	1.06	1.76	2.24	0.94	1.44	1.11	0.98	1.29	1.59	15.93
	S	19.3	10.9	6.7	2.4	1.1	T			0.1	1.4	8.6	16.5	66.9
Many Glacier	P[4]	4.40	3.40	3.05	2.65	3.05	4.30	2.23	2.67	2.98	2.60	3.55	4.15	39.03
Mountain View, AB	P	2.21	1.88	1.96	3.05	3.35	3.99	1.67	2.25	2.13	1.19	1.37	2.00	27.05
	S	21.9	18.8	19.6	24.7	6.1	1.0		T	6.7	9.2	13.2	20.0	141.2
Polebridge	P	3.07	2.04	1.47	1.42	1.93	2.35	1.20	1.46	1.41	1.73	2.31	2.93	23.32
	S	35.3	21.3	13.2	3.9	0.8	0.4			0.2	3.3	15.3	26.4	120.1
St. Mary	P[5]	2.88	2.15	1.77	2.00	2.60	3.30	1.50	1.82	2.00	1.55	2.25	2.60	26.42
	S	35.0	30.0	24.0	15.0	3.0	0.1			2.0	5.8	20.0	27.0	161.9
Summit	P	5.62	4.14	3.26	3.09	2.96	3.59	1.45	1.90	2.25	2.63	4.12	4.98	39.99
	S	56.8	41.4	32.9	26.0	8.1	0.7	T	T	5.3	13.7	34.6	47.8	267.3
Waterton Lakes, Belly R., AB	P	3.65	3.03	2.86	4.90	3.94	4.61	2.19	2.36	2.86	1.93	2.70	2.80	37.83
	S	35.2	29.0	26.9	39.5	9.4	1.9			3.8	10.3	21.9	24.7	202.6
Waterton Park Hqtrs., AB	P	4.63	3.90	3.47	4.56	3.73	4.17	1.58	2.57	3.38	3.01	3.22	3.98	42.20
	S	39.8	32.6	30.4	33.1	5.9	0.9			6.7	11.2	20.7	32.3	213.7
Waterton River Cabin, AB	P	3.59	2.40	2.33	3.63	3.29	4.58	1.72	2.39	2.50	2.01	2.31	2.87	33.60
	S	32.6	22.4	20.8	27.2	5.7	1.8			5.8	11.4	17.9	25.6	171.2
West Glacier	P	3.61	2.61	1.79	1.80	2.57	3.24	1.61	1.88	2.14	2.18	3.00	3.54	29.97
	S	43.4	25.9	15.7	4.1	0.8	0.3			0.2	2.2	16.6	35.9	145.1
Whitefish 5NW	P	2.44	1.81	1.33	1.56	2.48	3.09	1.36	1.78	1.53	1.46	2.05	2.41	23.30

[1] Montana and Alberta precipitation amounts may not be strictly comparable (see text).
[2] Includes estimates for much missing data.
[3] Estimated normal values based on only 8 years of data comparison with long-term stations.
[4] Estimated normal values based on only 6 or 7 years of data, mostly from site near hotel but also from ranger station.
[5] Normal values estimated from records since 1972, unofficial prior to 1981; snowfall averages unadjusted except for rounding.

Table 20.--Monthly and annual precipitation by individual years at Polebridge, West Glacier, Summit, and East Glacier. T denotes trace, amount too small to measure (less than 0.01 inch). M denotes amount missing, no estimate made. E denotes amount estimated in whole or part, different from originally published value or estimate; may include use of recording gauge data (except at East Glacier). P denotes estimate as published

Polebridge

Year	Precipitation												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Inches												
1934	3.14	0.29	2.98	1.45	1.40	1.88	0.05	0.59	1.00	3.34	2.94	2.91	21.97
1935	6.21	.17	1.60E	1.31	.52	1.48	1.10	.80	.43	1.32	1.40	.64	16.98
1936	3.45E	2.31	1.63	1.78	1.39	1.28	.25	.38	1.29	.39	.05	2.82	17.02
1937	1.25	2.97	.50E	2.40	1.31	1.87	.59	.89	1.47	1.45	2.50	3.55	20.75
1938	1.40	2.22	1.64	1.43	2.00	1.95	1.91	.97	1.03	2.63E	1.90E	4.22	23.30
1939	M												M
1940	M												M
1941	M										2.66	3.24	M
1942	.58	.99	.85E	1.60E	3.79	3.50E	1.81	1.16	1.67	1.09	3.47	1.35	21.86
1943	3.37	1.37	2.04	.74	1.77	1.98	.72	1.24	.33	1.78	.43	1.49	17.26
1944	.81	.89	.86	.68	2.01	1.98	.41	1.45	1.18	.25	1.11	.85E	12.48
1945	2.05E	1.64	2.29	2.25	1.35	1.98	1.59	.91	2.08	1.79	3.69	2.00	23.62
1946	2.14	1.49	1.44	.63P	1.50P	2.19	1.03	1.11	1.28	2.92P	5.31	2.06	23.10
1947	2.08	1.39	1.73	.36	.90	2.97	.32	2.99	.67	3.70	.85	1.22	19.18
1948	1.54	2.69	1.74	2.24	1.88	3.44	3.74	1.16	.09	.52	2.58	2.06	23.68
1949	1.07	4.38	1.25	1.08	2.18	1.37	2.74	.63	1.01	1.32	2.96	3.06	23.05
1950	4.28	1.74	2.73	.88	.70	1.61	1.02	.96	.70	3.51	2.07	2.34	22.54
1951	3.48	3.19	2.05	1.26	2.45	2.55	1.38	3.14	2.91	4.34	1.77	4.69	33.21
1952	2.19	.99	.59	.48	1.40	3.35	.90	.72	.39	.07	.49	1.50	13.07
1953	6.32	1.86	.86	2.47	1.70	3.10	.08	1.14	.96	.43	2.32	4.13	25.37
1954	6.92	3.04	2.93	3.39	.97	1.65	.96	4.81	.91	1.16	1.55	.96	30.25
1955	.67	1.94	1.95	1.01	1.36	1.68	2.14	T	1.37	2.77	2.86	4.47	22.22
1956	1.99	1.51	1.82	1.81	1.40	2.45	1.60	1.09	1.34	1.44	.64	2.99	20.08
1957	1.54	3.27	.71	1.52	1.89	3.44	1.58	.54	.43	3.31	.53	2.75	21.51
1958	1.99	2.64	1.09	2.57	1.18	3.59	.74	1.09	2.06	1.68	4.21	2.49	25.33
1959	5.54	1.97	.52	2.71	3.38	1.40	.11	1.21	4.45	3.22	4.79	1.57	30.87
1960	1.44	1.25	1.59	1.12	2.47	.61	.10	1.86	.56	1.12	4.08	1.17	17.37
1961	1.69	3.57	.77	2.07	3.46	.54	1.69	.64	2.44	2.87	1.54	3.88	25.16
1962	1.38	1.27	1.71	1.43	1.77	.71	1.59	1.16	.90	2.21	3.12	2.49	19.74
1963	1.65	1.98	1.72	.90	.94	4.35	.81	1.57	1.58	1.28	2.48	1.77	21.03
1964	2.74	.72	2.52	.94	3.14	3.21	1.09	1.35	1.87	1.44	2.64E	5.31	26.97
1965	2.90	2.47	.64	2.83E	1.11	2.41	.91	1.71	2.51	.50	2.34	2.19	22.52
1966	3.35	.80	1.79	1.26	1.35	5.50	1.74E	.90	.75	2.04	4.12	2.18	25.78
1967	3.92	1.61	2.10	.51	.87	.86	T	T	.09	4.37E	1.48P	2.77	18.58
1968	1.68P	1.68P	.88P	.84P	2.94	1.84	.77	2.82	2.95	2.15	1.61	3.07	23.23
1969	5.38	.69	.75	1.17	1.18	3.67	.31	.00	1.22	1.19	.63E	1.70E	17.89
1970	3.94	1.63	1.40	.54	2.23	2.56	.95	.28	2.33	.99	4.01	5.14	26.00
1971	6.79	2.28	2.85	.80	2.75	5.28	2.17	1.55	.48	2.07	2.36	4.54	33.92
1972	5.36	3.31	1.81	1.72	1.41	1.65	1.66	1.08	1.70	1.65	.46	3.76	25.57
1973	1.91	1.31	1.31	1.16	.94	1.54	.37	1.00	1.19	1.37	6.08	3.34	21.52
1974	5.80	2.79	2.51	1.89	1.22	1.21	.60E	1.05	1.07	.10P	3.15	2.34	23.73
1975	3.10	3.36	1.39	.83	1.79	1.96	1.80	2.79	.51	3.99	1.59	2.98	26.09
1976	2.21	3.29	.94	.91	1.98	2.40	2.18	2.99	.70	.68	1.29	.71	20.28
1977	1.04	.66	1.64	.46	1.87	.79	1.57	2.25	1.66	.70	2.16	3.56	18.36
1978	1.38	.82	.49	1.29	3.30	1.29	3.42	2.64	1.28	.46	1.80	1.73	19.90
1979	1.21	3.53	1.45	1.95	1.53	1.32	.60	1.26	.29	1.91	.18	2.17	17.40
1980	2.60E	1.64	1.41	.72	3.83	3.71	1.31	1.24	1.24	.34	2.94	5.69	26.67
1981	.87	1.67	.76	1.77	3.04	3.88	1.35	.66	.77	.61	2.03	2.73	20.14
1982	4.00	3.81	2.43	2.26	.42	4.12	1.40	.66	2.15	.98	2.41	3.20	27.18
1983	2.38	1.14	1.87	1.12	.29	2.98	3.05	1.06	1.15	.56	2.74	1.72	20.06
1984	1.48	.51	1.03	1.15	2.73	1.61	.67	1.32	2.61	2.38	2.74	2.35	20.58
1985	.05	1.62	.82	1.04	1.01	2.06	.41	1.44	2.58	2.58	2.36	.48	16.45
10-year averages													
1941-50[2]	1.99	1.70	1.59	1.07	1.87	2.21	1.42	1.24	1.13	1.80	2.51	1.97	20.50
1951-60	3.21	2.17	1.41	1.83	1.82	2.38	1.06	1.56	1.54	1.95	2.32	2.67	23.92
1961-70	2.86	1.64	1.43	1.25	1.90	2.57	.99	1.04	1.66	1.90	2.40	3.05	22.69
1971-80	3.14	2.30	1.58	1.17	2.06	2.12	1.57	1.79	1.01	1.33	2.20	3.08	23.35

(con.)

Table 20. (Con.)

West Glacier, Park Headquarters

Year	Precipitation												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Inches												
1921	4.35	2.91	4.26	1.75	0.87	2.55	0.72	0.96	2.61	1.54	5.05	2.95	30.52
1922	2.82	1.88	.70	2.24	1.70E	.59	2.19	1.29	1.27	2.59	1.45	6.53	25.25
1923	6.69	3.00E	.85E	1.20E	3.22	2.76	2.28	2.10	.21	3.123	3.88	4.59	33.90
1924	2.86	3.71	1.50E	.37	.45	5.21	.50	1.16	1.75E	2.90	2.11	5.26	27.78
1925	5.23	3.17	3.54	M	M	M	M	M	M	1.07	.98	2.38	M
1926	2.64	2.88	.22	.56	1.09	.80	.75	3.28	4.13	2.61	5.09	2.73	26.78
1927	4.21	4.06	1.68	1.01	2.98	2.40	1.05	1.50E	3.83	3.85	4.88	2.94	34.39
1928	1.79	.33	1.95	2.04	.62	3.94	1.90	.60	.09	2.07	1.57	2.19	19.09
1929	2.23	1.96	2.06	1.60	1.97	1.45	T	.36	.91	1.07	.46	6.02	20.09
1930	1.68	2.30	.87	2.27	2.59	2.16	1.07	.18	2.44	5.64	2.26	.97	24.43
1931	1.29	1.15	2.70	.98	2.44	2.52	1.94	T	3.47	1.44	1.65	3.14	22.72
1932	3.29	3.71	4.43	2.22	2.45	1.53	1.60	2.16	.56	2.44	6.03	3.91	34.33
1933	4.16	2.76	1.41	1.34	1.56	3.48	.05	2.91	3.21	5.96	2.60	7.53	36.97
1934	3.60	.21	3.17	1.08	1.86	2.19	.34	.32	1.00	2.75	3.26	2.93	22.71
1935	4.59	.44	1.64	1.09	1.15	1.61	1.12	.82	.52	1.00	2.38	1.07	17.43
1936	4.76	2.48	1.85	1.19	3.36	2.40	.38	.17	1.25	.91	.27	4.02	23.04
1937	2.40	2.99	.64	3.25	2.03	3.10	.72	.99	1.53	2.61	3.89	3.82	27.97
1938	2.30	1.95	.68	1.67	3.73	2.07	1.59	1.90	.79	2.71	2.41	4.68	26.48
1939	3.49	2.08	1.32	.99	1.88	4.15	.79	.29	1.39	.81	1.57	3.37	22.13
1940	1.32	5.87	2.00	2.62	1.65	1.72	1.56	.06	1.99	2.01	3.53	2.92	27.25
1941	2.91	.46	.51	.39	3.50	1.71	.75	.48	3.78	1.53	3.19	3.01	22.22
1942	.74	1.46	.94	2.10	4.29	3.87	2.33	.62	1.73	2.29	3.71	3.36	27.44
1943	2.61	2.66	1.62	1.21	2.38	3.69	.50	.36	.74	3.65	.94	1.48	21.84
1944	.67	.88	1.36	1.32	2.62	2.00	.70	1.98	2.74	.27	2.55	1.50	18.59
1945	2.62	1.86	2.58	2.59	2.12	3.16	.20	.45	4.19	4.18	4.22	2.11	30.28
1946	3.96	1.78	1.33	2.05	3.12	3.77	1.78	1.15	2.09	5.43	6.75	3.98	37.19
1947	4.01	1.89	2.54	1.45	.76	6.00	.95	4.73	1.54	4.08	1.94	1.69	31.58
1948	2.27	3.05	1.47	4.50	2.86	3.90	3.79	.67	.39	.94	3.70	3.53	31.07
1949	1.29	4.20	1.56	1.08	2.27	2.12	1.93	.55	1.61	3.45	2.73	3.86	26.65
1950	4.71	2.32	3.46	1.63	.91	3.52	1.02	1.78	1.10	5.87	2.35	5.17	33.84
1951	4.77	4.88	1.89	1.67	3.08	2.92	1.75	2.59	4.00	4.92	2.25	4.25	38.97
1952	2.51	1.29	1.13	.27	3.17	4.56	1.56	1.44	1.94	.08	.68	2.43	21.06
1953	7.07	3.24	1.62	3.19	2.99	3.95	.09	1.17	.60	.89	2.73	4.78	32.32
1954	4.98	2.69	2.47	2.91	2.13	3.60	3.15	5.14	1.64	1.70	2.94	1.79	35.14
1955	1.58	2.33	1.55	1.49	1.82	2.75	4.10	.00	2.25	5.08	3.55	2.80	29.30
1956	2.50	2.50	1.94	1.89	1.09	2.66	1.53	1.67	1.77	3.27	1.05	4.78	26.65
1957	2.60	3.67	1.60	1.58	1.62	3.99	.73	.69	.35	2.68	1.36	3.57	24.44
1958	3.04	3.29	1.41	3.45	1.40	3.36	.97	.62	3.87	1.80	5.64	3.38	32.23
1959	5.31	2.29	1.49	2.62	3.05	2.33	.05	1.55	4.08	2.69	7.52	1.15	34.13
1960	2.63	2.33	2.06	2.14	3.65	1.96	.00	2.75	.59	1.70	4.52	1.84	26.17
1961	2.20	4.73	2.12	2.57	3.29	.88	2.20	.76	3.33	1.75	2.18	4.05	30.06
1962	1.68	1.40	2.97	2.53	3.33	.76	.58	1.03	1.65	3.01	3.96	2.96	25.86
1963	2.24	3.54	2.25	1.39	1.16	6.64	1.70	.79	1.80	1.88	3.03	1.93	28.35
1964	3.74	1.33	3.68	1.50	4.62	4.81	3.50	1.51	2.71	2.28	4.28	7.42	41.38
1965	3.91	3.63	.47	3.33	1.06	3.79	2.25	4.12	3.03	.71	2.14	1.78	30.22
1966	3.66	1.59	2.27	.52	1.56	6.35	1.77	1.69	.75	2.69	4.35	5.03	32.23
1967	5.43	1.66	1.51	.62	1.15	1.94	.11	.17	.70	4.03	2.48	2.83	22.63
1968	1.97	2.58	1.57	1.15	4.94	3.22	.86	3.66	6.17	4.16	2.38	4.04	36.70
1969	6.67	.66	.71	1.61	1.90	4.55	.48	.01	3.20	1.98	1.16	1.64	24.57
1970	5.31	3.56	1.97	1.38	3.41	3.73	1.73	.70	3.21	1.93	4.74	3.72	35.39
1971	5.55	2.14	2.28	.95	2.84	5.94	1.75	1.91	1.24	2.88	3.77	4.90	36.15
1972	5.13	5.07	2.76	1.57	2.13	2.69	1.99	1.60	1.62	1.05	1.20	4.83	31.64
1973	2.48	1.07	1.26	1.59	2.09	2.32	.22	1.24E	2.62	2.59	4.63	3.27	25.38
1974	5.77	2.98	2.87	2.47	2.18	2.24	1.37	1.12	1.32	.14	4.53	2.52	29.51
1975	4.45	2.58	1.67	1.17	2.19	2.54	2.00	4.06	1.14	4.17	2.81	3.78	32.56
1976	3.75	3.08	.96	1.88	2.83	3.29	3.05	4.09	.80	.30	1.32E	1.91	27.26
1977	1.29	1.40	2.16	.33	2.13	.75	3.13	2.55	3.24	1.17	3.05E	6.02	26.87
1978	2.83	1.06	.51	2.43	3.68	2.12	3.04	4.48	1.64	.64	2.14	2.56	27.13
1979	1.05	3.59	1.23	2.60E	2.66	1.47	1.12	.85	.80	2.37	.65	2.64	21.03
1980	2.26	2.04	1.15	1.24	3.96	5.12	1.62	2.37	2.27	.86	2.89	7.72	33.50
1981	1.32	2.46	1.32	2.55	3.96	6.83	1.67	1.70	1.14	.90	2.76	2.43	29.04
1982	4.10	5.10	1.43	2.66	1.40	2.48	2.58	.89	2.12	1.80	3.48	3.62	31.66
1983	4.36	1.41	1.90	1.43	.96	4.41	4.70	.52	1.41	1.56	3.80	2.72	29.18
1984	3.02	1.01	2.07	2.16	3.54	2.83	.42	.73	3.61	3.36	3.46	3.19	29.40
1985	.16	1.66	1.32	1.16	1.75	1.60	.09	2.08	4.83	2.52	3.00	.81	20.98
10-year averages													
1921-30[1]	3.45	2.62	1.76	1.45	1.72	2.43	1.16	1.27	1.92	2.65	2.77	3.66	26.86
1931-40	3.12	2.36	1.98	1.64	2.21	2.48	1.01	.96	1.57	2.26	2.76	3.74	26.10
1941-50	2.58	2.06	1.74	1.83	2.48	3.37	1.40	1.28	1.99	3.17	3.21	2.97	28.07
1951-60	3.70	2.85	1.72	2.12	2.40	3.21	1.39	1.76	2.11	2.48	3.22	3.08	30.04
1961-70	3.68	2.47	1.95	1.66	2.64	3.67	1.52	1.44	2.66	2.44	3.07	3.54	30.74
1971-80	3.46	2.50	1.69	1.62	2.67	2.85	1.93	2.43	1.67	1.62	2.70	4.02	29.16

(con.)

Table 20.--(Con.)

Summit

Year	Precipitation												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Inches												
1935	M	0.59	4.48	3.69	1.49	1.44	0.84	0.54	1.21	1.36	1.23	0.95	M
1936	6.28	3.96	3.92	1.23	1.21	2.60	.59	1.34	1.73	2.10	.64	5.34	30.94
1937	2.24	4.78	1.15	2.75	1.82	5.52	.27	1.09	2.23	2.48	2.96	5.20	32.49
1938	3.19	2.95	3.73	2.78	5.27	2.94	2.23	1.54	1.24	3.78	4.27	5.96	39.88
1939	4.01	1.94	2.40	2.40	1.78	3.41	.41	.78	1.95	2.06	.86	3.30	25.30
1940	.94	5.51	1.62	3.75	1.16	1.36	1.18	.67	4.50	1.68	2.95	1.74	27.06
1941	2.03	.67	.98	1.02	3.92	5.47	1.31	1.07	4.37	2.03	3.29	5.10	31.26
1942	.45	1.32	2.69	1.07	5.13	4.38	2.09	1.42	3.60	1.87	7.43	3.42	34.87
1943	4.86	3.70	3.50	2.69	3.86	6.81	.44	.70	1.97	2.89	1.12	1.63	34.17
1944	1.68	1.86	2.58	.60	4.37	3.00	.45	2.58	3.28	.84	2.36	1.86	25.46
1945	3.15	2.98	3.62	4.15	2.12P	4.79P	.88	.92	3.28	2.77	4.45	3.03	36.14
1946[3]	4.23	2.77	2.05	.85	1.49	2.80	1.25	2.85	1.98	7.16	7.28	5.34	40.05
1947[3]	3.43	2.38	3.17	1.21	1.12	3.69	.45	3.05	1.95	4.51	2.36	2.32	29.64
1948	5.04	5.69	4.26	3.34	3.81	6.68	1.78	.60	.78	1.23	5.54	5.30	44.05
1949	2.29	6.27	2.40	2.04	4.18	1.40	1.59	.62	3.17	3.06	5.13	8.73	40.88
1950	9.35	3.55	4.94	3.12	1.87	5.44	2.02	1.89	1.69	7.53	5.92	5.95	53.27
1951	5.51	6.58	3.93	3.01	3.21	4.32	2.31	2.95	4.36	6.20	3.20	4.65	50.23
1952	4.35	2.15	2.55	.65	2.30	4.05	1.05	2.00	1.55	.75	1.63	3.12	26.15
1953	14.00	4.50	3.20	5.78	6.29	5.10	.21	1.03	2.38	.34E	4.15E	6.53E	53.51
1954	8.52	5.24	3.27	4.45	2.04	3.03	1.52	2.52	3.42	3.32	3.57	3.71	44.21
1955	1.66	2.50	4.52	1.75	3.13	3.89	3.49	.00	2.16	5.03	7.81	6.39	42.33
1956	3.76	5.56	4.73	2.55	2.00E	2.72E	1.60	3.23	2.19	3.53	2.58	6.85	41.30
1957	2.43	6.23	1.67	2.67	2.75	4.45	1.06	.95	1.30	2.24	1.99	6.11	33.85
1958	3.33	2.80	1.38	4.75	1.25	5.50	2.81	.81	4.03	2.47	8.21	4.20	41.54
1959	6.05	3.48	4.09	4.98	3.00	.95	.19	1.62	4.02	4.90	6.20	2.94	42.42
1960	3.64	2.02	3.26	4.91	2.82	1.49	.12	2.71	1.05	2.20	6.08	2.50	32.80
1961	3.55	8.37	2.83	4.95	2.80	.27	1.50	.40	5.53	3.69	4.55	5.15	43.59
1962	2.70	2.39	4.06	3.75	4.22	1.77	1.89	2.30	1.38	3.55	5.14	4.65	37.80
1963	2.85	3.72	3.29	1.80	1.60	5.65	1.80	.25	1.60	1.85	3.90	2.45	30.76
1964	5.95	2.50	4.30	3.55	7.15	8.89	2.25	1.50	2.75	4.45	3.90	8.20	55.39
1965	5.35	6.15	1.85	4.45	2.06E	3.33	.90	2.62	4.25	.55	4.60	3.50	39.61
1966	4.50	2.90	3.05	2.05	2.50	4.10	1.50	2.70	.20	3.05	5.65	3.95	36.15
1967	9.60	5.55	3.90	2.30	2.35	4.60	.29	.10	.80	5.05	1.97P	6.09	42.60
1968	4.37	2.99	3.25	2.18	2.09E	3.36E	.81	3.55	4.77	4.11E	2.70	6.16	40.34
1969	8.96	1.30P	1.92	1.06	2.13	5.58	.27	.18	1.70E	1.74	1.63	2.55	29.02
1970	6.83	5.73	3.86E	6.21	3.21	2.96	1.79E	1.33	2.37E	1.51E	4.48	6.03	46.31
1971	10.19	3.44	5.01	3.84	2.24E	3.12	1.20	1.20	1.77	3.08E	2.90E	7.89	45.88
1972	13.43	6.64	3.73E	2.55E	1.30	1.44	3.69	3.13	2.13	1.74	.87	5.01	45.66
1973	3.43	1.34	1.61	2.82	2.14	2.47	.03	.86	1.85	1.75	6.60	4.85	29.75
1974	9.95E	5.20	7.03	2.74	3.57	1.77	1.04	1.91	.78	.65	7.70	4.27	46.61
1975	5.80E	3.80	2.59	2.47	4.68	9.58	1.50	3.50	1.12	4.23	2.93	3.45	45.65
1976	4.77	6.17	1.70	1.70	2.05	2.40	1.66	3.06	.98	.41	2.34E	2.50E	29.74
1977	1.78E	1.33	2.84	.77	2.14	.50	1.98	4.28	2.21	1.72	5.62	7.21	32.38
1978[4]	4.11	2.49	1.92	2.86	5.47	2.01	3.28	2.47	2.02	1.25E	6.04	5.58	39.50
1979[4]	3.59	8.52	2.17	2.81	1.8	2.2	1.1	.8	1.0	1.9	.6 E	6.3	32.79
1980	3.6	2.4	4.4	2.2	4.5 E	6.1	.7	3.0	1.8	1.5	4.2	6.6 E	41.0
1981	.8	3.4	1.4	3.5	6.4	5.2	2.2	1.2	.9	1.6	2.7	5.0	34.3
1982	M	6.2	4.6	3.4	4.2	2.4	1.8	1.2	2.3	1.0	4.7	M	M
1983	M	M	M	1.5	1.7	2.6	2.5	.7	3.7	1.5	3.8	2.6	M
1984	2.6	1.2	2.9	2.9	3.8	3.3	.4	1.1	5.5	4.6	4.8	6.3	39.4
1985	.2	3.1	1.4	3.1	4.3	2.2	.2	3.1	7.1	6.1	3.6	1.0	35.4
10-year averages													
1941-50	3.65	3.12	3.02	2.01	3.19	4.45	1.23	1.57	2.61	3.39	4.49	4.27	36.98
1951-60	5.33	4.11	3.26	3.55	2.88	3.55	1.44	1.78	2.65	3.10	4.54	4.70	40.89
1961-70	5.47	4.17	3.23	3.23	3.01	4.05	1.30	1.49	2.54	2.96	3.85	4.87	40.17
1971-80	6.07	4.13	3.30	2.48	2.99	3.16	1.62	2.42	1.57	1.82	3.98	5.37	38.91

(con.)

Table 20. (Con.)

East Glacier

Year	Precipitation												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	Inches												
1950	8.78	2.01	2.28	1.68	0.41	4.01	2.12	1.63	1.00E	5.46	6.89	2.97	39.24
1951	4.25	3.90	2.03	2.12	3.28	5.35	2.27	2.77	5.40	3.39	4.88	2.71	42.35
1952	1.77	1.18	1.57	.94	2.32	2.72E	2.99	1.95	.99	.80	.99	1.92	20.14
1953	9.49	2.75E	3.07	5.25P	6.68	6.61	.40	.72E	1.13	.21	3.59	3.44	43.34
1954	11.91	4.43E	4.96	4.78	1.19	1.20	.71	1.28	2.78	2.36	1.35	1.58	38.53
1955	.60	3.93	4.84	1.76	4.27	2.01	3.29	T	1.52	3.29	5.85E	4.02E	35.38
1956	2.10E	4.88E	3.72E	2.13E	3.29	1.97	2.75	2.80	1.37E	1.59	2.42	3.57	32.59
1957	2.29	5.01	.88	1.59	3.65	3.60	.63	1.18	1.71	1.83	.63	3.57	26.57
1958	1.35	1.24	1.09	2.81	1.33	7.07	3.38	.74	2.78	1.73	7.84	2.99	34.35
1959	4.52	2.24	1.85	4.80	2.30	1.24	.13	1.18	3.14	3.85	3.70	1.98	30.93
1960	2.11	1.30	1.82	2.72	1.51	1.00	.12	1.90	.60	.80	3.66	1.37	18.91
1961	2.40	6.00	2.44	3.21	2.11	.13	1.81	.43	4.18P	2.18	2.87	3.53	31.29
1962	1.86P	1.71P	3.12	1.65	2.56	1.31	2.41	.84	.85	1.83	3.34	3.31	24.79
1963	1.52	2.15	2.68	1.56	1.04	3.88	1.20	.50	1.70	1.26	2.98	1.43	21.90
1964	2.84	1.22	2.66	2.40	5.65	8.79	1.44	1.23	2.72	3.15	2.70	6.51	41.31
1965	4.14	4.65	2.28	2.99	1.78	2.92	.78	2.20	3.19	.56	3.31	2.57	31.37
1966	5.49	1.76	1.37	1.53	1.85	2.76	1.13	2.17	.24	1.99	4.57	1.38	26.24
1967	4.58	3.57	2.32	3.08	2.78	3.97	.05	T	.37	4.99	2.49	2.98	31.18
1968	2.43	1.45	2.10	1.52	2.38	3.03	.63	2.93E	3.21P	1.90	1.54	4.07	27.19
1969	9.35	.83	.80	.60	.70	5.75	.30	.11P	1.35P	1.25E	1.08E	1.53	23.65
1970	4.02	3.28	3.17	4.50	2.79	4.04	1.16	1.17	2.23	1.06	4.13	3.11	34.66
1971	8.63	1.54	3.79	2.12	2.08	2.04	1.64	2.04	1.17	3.37	1.65	5.87	35.94
1972	11.34	5.96	3.35	2.29	1.84	2.23	3.37	3.44	2.54	1.36	.14	4.17	42.03
1973	1.67	.91	.87	2.31	1.38	1.22	.06	.63	.75	1.69	4.15	1.57	17.21
1974	6.20	1.85	4.16	.66	1.95	1.22	.94	1.82	1.09	.38	2.66	1.51	24.44
1975	2.98	3.14	1.85	2.60	4.29	10.86	1.46	2.60	.40E	3.70	3.02	6.22	43.12
1976	2.29	4.22	.83	2.04	1.13	1.30	1.26	2.57	1.35	.15	1.59	1.85	20.58
1977	.93	.53	1.84	.28	1.37	.85	1.24	5.85	2.32	1.34	4.62	6.05	27.22
1978	2.94	1.50	.40	2.38	2.86	1.85P	3.62	1.68P	3.15	1.28	4.77	3.44	29.87
1979	.82	4.07	2.69	2.87	1.99	2.45	.82	1.90	.52	.94	.24	5.74	25.05
1980	2.29	1.51	2.26	2.11	6.37	4.18	.17	4.21	1.65	1.03	2.92	4.04	32.74
1981	.36	1.72	.50	1.62	5.75	2.21	1.50	.74	.36	.96	1.72	2.97	20.41
1982	4.57	3.87	3.14	1.61	2.81	1.88	.57	.94	1.79	.49	2.40	2.89	26.96
1983	3.32	1.07	2.29	.38	.86	2.57	2.32	.44	2.28	.39	2.11	1.50	19.53
1984	1.88	.41	1.30	2.66	1.96	3.41	.59	1.09	4.08	3.97	1.60	4.10	27.05
1985	.26	1.85	1.74	1.93	3.14	1.52	.25	3.23	5.93	3.32	2.67	.40	26.24
10-year averages													
1951-60	4.04	3.09	2.58	2.89	2.98	3.28	1.67	1.45	2.14	1.99	3.49	2.72	32.32
1961-70	3.86	2.66	2.29	2.30	2.36	3.66	1.09	1.16	2.00	2.00	2.93	3.04	29.37
1971-80	4.01	2.52	2.20	1.97	2.53	2.82	1.46	2.67	1.49	1.52	2.58	4.05	29.82

[1] 9-year average for months April through September.
[2] 9-year average for January through October adjusted to 10-year period.
[3] Data from gauge equipped with windshield beginning June 1947.
[4] Listed data from Fischer-Porter recording gauge beginning May 1979; amounts in one-tenth inch increments.

Table 21.--Precipitation statistics for West Glacier, Polebridge, and Summit; amounts in inches. Based on years 1949-78; see tables 18 and 20 for longer period averages and extremes. Number .00 denotes either zero or trace. Year (YR), first two digits omitted, is the most recent in cases of more than one occurrence

P R E C I P I T A T I O N BY 10 (OR 11)-DAY AND MONTHLY PERIODS

STATION NUMBER 248809 WEST GLACIER YRS 1949-1978

		10-DAY AND MONTHLY TOTALS							MAXIMUM DAILY TOTALS			
PERIOD BEGINS	NO. YRS	MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT. YR		LOWEST TOT.YR		EXTREME	YR	AVG MAX	STD DEV	MEDIAN
JAN 1	30	1.056	0.753	0.945	3.64	69	0.05	77	1.25	69	0.422	0.299	0.350
JAN 11	30	1.338	0.840	1.230	3.19	74	0.08	65	1.24	50	0.485	0.290	0.495
JAN 21	30	1.307	0.847	1.145	3.08	71	0.00	77	1.43	71	0.530	0.351	0.455
FEB 1	30	0.964	0.877	0.740	4.23	51	0.00	76	2.09	51	0.420	0.436	0.335
FEB 11	30	0.972	0.823	0.655	3.17	70	0.01	78	1.14	61	0.416	0.306	0.300
FEB 21	30	0.701	0.615	0.575	2.43	72	0.02	67	1.12	58	0.373	0.320	0.295
MAR 1	30	0.643	0.497	0.675	2.04	64	0.00	78	0.74	64	0.279	0.209	0.245
MAR 11	30	0.500	0.453	0.400	2.03	50	0.00	54	0.90	50	0.227	0.184	0.175
MAR 21	30	0.730	0.510	0.690	2.12	62	0.00	66	0.69	63	0.295	0.169	0.265
APR 1	30	0.450	0.408	0.320	1.55	62	0.00	49	0.79	62	0.232	0.190	0.215
APR 11	30	0.634	0.629	0.465	2.53	65	0.05	75	1.30	65	0.312	0.279	0.240
APR 21	30	0.680	0.501	0.630	2.01	53	0.00	77	1.41	74	0.376	0.317	0.320
MAY 1	30	0.821	0.889	0.550	4.06	64	0.01	66	1.57	64	0.386	0.370	0.265
MAY 11	30	0.758	0.593	0.640	2.22	71	0.02	73	1.05	59	0.381	0.285	0.295
MAY 21	30	0.876	0.788	0.620	3.57	68	0.04	58	1.43	68	0.419	0.358	0.290
JUN 1	30	1.197	1.169	0.805	4.85	66	0.00	60	3.47	64	0.675	0.797	0.400
JUN 11	30	0.863	0.767	0.785	3.33	65	0.00	55	1.52	65	0.449	0.388	0.455
JUN 21	30	1.150	1.013	0.885	4.13	63	0.00	77	1.70	71	0.555	0.445	0.435
JUL 1	30	0.802	0.761	0.530	2.60	55	0.00	67	1.68	64	0.432	0.387	0.310
JUL 11	30	0.441	0.490	0.220	1.82	76	0.00	73	1.20	78	0.289	0.326	0.115
JUL 21	30	0.378	0.458	0.180	1.79	77	0.00	60	1.64	77	0.256	0.356	0.140
AUG 1	30	0.385	0.458	0.220	1.85	76	0.00	59	0.95	60	0.248	0.269	0.160
AUG 11	30	0.523	0.749	0.065	2.96	78	0.00	71	1.12	76	0.261	0.325	0.060
AUG 21	30	0.940	0.916	0.660	3.69	54	0.00	70	1.73	54	0.462	0.386	0.415
SEP 1	30	0.664	0.530	0.595	1.92	52	0.00	56	1.59	52	0.413	0.338	0.385
SEP 11	30	0.692	0.784	0.540	3.88	68	0.00	60	1.50	68	0.383	0.345	0.315
SEP 21	30	0.777	0.759	0.485	2.62	69	0.00	75	0.94	51	0.353	0.279	0.280
OCT 1	30	0.758	0.765	0.610	3.40	55	0.00	71	1.76	55	0.375	0.362	0.330
OCT 11	30	0.750	0.829	0.555	3.01	50	0.00	78	1.49	50	0.370	0.384	0.250
OCT 21	30	0.875	0.632	0.815	2.17	67	0.00	62	1.55	49	0.417	0.352	0.350
NOV 1	30	0.792	0.589	0.680	2.36	58	0.02	57	1.21	73	0.434	0.313	0.380
NOV 11	30	1.170	0.824	1.120	4.18	59	0.14	61	1.20	59	0.490	0.292	0.455
NOV 21	30	1.086	0.741	0.940	3.42	64	0.00	56	1.30	64	0.475	0.300	0.415
DEC 1	30	1.107	0.803	0.990	3.30	77	0.08	59	1.17	75	0.420	0.304	0.335
DEC 11	30	1.122	0.666	1.140	2.65	56	0.02	76	0.88	56	0.462	0.203	0.455
DEC 21	30	1.271	0.927	1.100	4.47	64	0.16	63	2.38	64	0.496	0.435	0.425
MONTH													
JAN	30	3.701	1.644	3.700	7.07	53	1.17	49	1.43	71	0.754	0.323	0.735
FEB	30	2.637	1.186	2.540	5.07	72	0.66	69	2.09	51	0.729	0.405	0.635
MAR	30	1.872	0.781	1.780	3.68	64	0.47	65	0.90	50	0.440	0.177	0.430
APR	30	1.764	0.857	1.595	3.45	58	0.27	52	1.41	74	0.526	0.327	0.445
MAY	30	2.456	1.043	2.180	4.94	68	0.91	50	1.57	64	0.717	0.379	0.595
JUN	30	3.209	1.487	3.070	6.64	63	0.75	77	3.47	64	1.029	0.718	0.845
JUL	30	1.620	1.112	1.710	4.10	55	0.00	60	1.68	64	0.608	0.444	0.565
AUG	30	1.848	1.418	1.530	5.14	54	0.00	55	1.73	54	0.618	0.364	0.610
SEP	30	2.132	1.334	1.705	6.17	68	0.35	57	1.59	52	0.648	0.333	0.595
OCT	30	2.383	1.510	2.130	5.87	50	0.08	52	1.76	55	0.679	0.416	0.695
NOV	30	3.049	1.534	2.770	7.52	59	0.68	52	1.30	64	0.724	0.256	0.655
DEC	30	3.500	1.464	3.475	7.42	64	1.15	59	2.38	64	0.722	0.392	0.610

(con.)

Table 21. (Con.)

P R E C I P I T A T I O N BY 10 (OR 11)-DAY AND MONTHLY PERIODS

STATION NUMBER 246615 POLEBRIDGE YRS 1949-1978

		10-DAY AND MONTHLY TOTALS							MAXIMUM DAILY TOTALS				
PERIOD BEGINS	NO. YRS	MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT.	YR	LOWEST TOT.	YR	EXTREME	YR	AVG MAX	STD DEV	MEDIAN
JAN 1	29	0.928	0.735	0.900	3.15	53	0.00	58	1.53	53	0.361	0.291	0.290
JAN 11	29	1.236	1.009	0.980	4.29	74	0.07	65	1.18	74	0.460	0.325	0.310
JAN 21	29	1.007	0.755	1.010	3.00	54	0.00	77	1.28	54	0.391	0.313	0.320
FEB 1	29	0.709	0.507	0.700	1.83	75	0.00	77	1.03	63	0.343	0.255	0.320
FEB 11	29	0.758	0.678	0.570	2.38	61	0.00	78	1.10	61	0.339	0.280	0.260
FEB 21	29	0.577	0.543	0.400	1.92	57	0.00	67	0.95	72	0.314	0.283	0.230
MAR 1	29	0.580	0.448	0.580	1.65	64	0.03	65	0.88	72	0.272	0.213	0.260
MAR 11	29	0.378	0.364	0.220	1.43	50	0.00	58	0.81	50	0.191	0.184	0.140
MAR 21	29	0.572	0.520	0.390	2.24	54	0.05	53	1.50	54	0.289	0.292	0.220
APR 1	29	0.399	0.428	0.240	2.08	54	0.00	69	0.60	54	0.194	0.155	0.160
APR 11	29	0.472	0.422	0.410	1.89	65	0.01	52	1.04	65	0.244	0.207	0.190
APR 21	29	0.545	0.446	0.400	1.60	53	0.00	60	1.10	74	0.272	0.226	0.220
MAY 1	30	0.598	0.565	0.470	2.89	64	0.00	65	0.86	64	0.284	0.201	0.265
MAY 11	30	0.594	0.525	0.545	2.15	59	0.00	73	1.73	59	0.340	0.358	0.270
MAY 21	30	0.653	0.495	0.550	2.11	68	0.04	58	1.27	68	0.363	0.278	0.305
JUN 1	30	0.867	0.968	0.480	4.44	66	0.03	60	2.43	66	0.477	0.565	0.270
JUN 11	30	0.584	0.429	0.450	1.55	65	0.02	55	0.99	56	0.346	0.273	0.250
JUN 21	30	0.835	0.802	0.685	3.20	71	0.00	77	1.75	51	0.428	0.422	0.305
JUL 1	30	0.550	0.502	0.355	1.57	71	0.00	60	1.13	66	0.304	0.295	0.220
JUL 11	30	0.384	0.363	0.290	1.47	78	0.00	59	0.68	77	0.238	0.206	0.195
JUL 21	30	0.332	0.357	0.235	1.42	49	0.00	74	0.86	75	0.200	0.214	0.150
AUG 1	30	0.396	0.422	0.235	1.59	60	0.00	69	0.87	63	0.258	0.261	0.185
AUG 11	30	0.396	0.511	0.220	2.08	68	0.00	73	0.81	51	0.216	0.250	0.130
AUG 21	30	0.641	0.731	0.425	3.18	54	0.00	70	1.34	54	0.347	0.352	0.225
SEP 1	30	0.450	0.391	0.425	1.46	59	0.00	69	0.67	74	0.250	0.202	0.215
SEP 11	30	0.488	0.459	0.405	1.93	59	0.00	60	1.03	59	0.276	0.233	0.240
SEP 21	30	0.473	0.491	0.310	2.15	51	0.00	75	0.70	51	0.242	0.184	0.215
OCT 1	30	0.556	0.527	0.515	2.02	75	0.00	71	1.04	75	0.306	0.259	0.290
OCT 11	30	0.566	0.566	0.340	1.86	51	0.00	78	0.84	50	0.294	0.268	0.210
OCT 21	30	0.699	0.555	0.635	2.34	67	0.00	74	1.38	67	0.322	0.286	0.265
NOV 1	29	0.607	0.568	0.430	2.17	73	0.03	57	1.10	73	0.369	0.302	0.290
NOV 11	29	0.857	0.705	0.790	2.62	59	0.02	61	0.95	60	0.373	0.276	0.250
NOV 21	29	0.938	0.653	0.760	2.60	70	0.00	56	1.34	58	0.448	0.336	0.360
DEC 1	30	0.897	0.700	0.675	2.60	70	0.04	78	0.90	70	0.358	0.235	0.330
DEC 11	30	0.902	0.611	0.870	2.52	55	0.02	76	1.11	55	0.388	0.262	0.340
DEC 21	30	1.054	0.755	0.850	3.05	64	0.01	56	1.27	64	0.412	0.288	0.390
MONTH													
JAN	29	3.171	1.891	2.740	6.92	54	0.67	55	1.53	53	0.629	0.338	0.520
FEB	29	2.044	1.010	1.940	4.36	49	0.66	77	1.10	61	0.566	0.274	0.500
MAR	29	1.530	0.733	1.590	2.93	54	0.49	78	1.50	54	0.450	0.286	0.360
APR	29	1.417	0.771	1.180	3.39	54	0.46	77	1.10	74	0.401	0.226	0.340
MAY	30	1.845	0.818	1.730	3.46	61	0.70	50	1.73	59	0.587	0.326	0.490
JUN	30	2.286	1.316	1.890	5.50	66	0.54	61	2.43	66	0.756	0.559	0.560
JUL	30	1.265	0.831	1.215	3.42	78	0.00	67	1.13	66	0.438	0.296	0.410
AUG	30	1.432	1.089	1.115	4.81	54	0.00	69	1.34	54	0.512	0.332	0.455
SEP	30	1.411	0.955	1.205	4.45	59	0.09	67	1.03	59	0.418	0.198	0.400
OCT	30	1.821	1.249	1.435	4.57	67	0.07	52	1.38	67	0.520	0.302	0.565
NOV	29	2.402	1.397	2.320	6.08	73	0.46	72	1.34	58	0.640	0.322	0.550
DEC	30	2.853	1.237	2.760	5.31	64	0.71	76	1.27	64	0.593	0.255	0.520

(con.)

Table 21. (Con.)

P R E C I P I T A T I O N BY 10 (OR 11)-DAY AND MONTHLY PERIODS

STATION NUMBER 247978 SUMMIT YRS 1949-1978

PERIOD BEGINS	NO. YRS	10-DAY AND MONTHLY TOTALS MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT.	YR	LOWEST TOT.	YR	I	MAXIMUM DAILY TOTALS EXTREME	YR	AVG MAX	STD DEV	MEDIAN
JAN 1	30	1.991	1.421	1.705	6.00	53	0.23	77	I	2.95	53	0.801	0.655	0.720
JAN 11	30	2.120	1.641	1.795	6.48	72	0.20	65	I	2.11	72	0.677	0.503	0.610
JAN 21	30	1.659	1.152	1.430	3.93	71	0.00	77	I	1.85	71	0.608	0.435	0.560
FEB 1	30	1.400	1.009	1.210	5.06	51	0.01	77	I	1.67	51	0.520	0.369	0.475
FEB 11	30	1.527	1.204	1.180	4.65	61	0.26	69	I	2.50	61	0.605	0.534	0.450
FEB 21	30	1.169	0.888	0.890	3.43	56	0.04	73	I	1.10	72	0.491	0.301	0.460
MAR 1	30	1.165	0.663	1.195	2.57	72	0.14	76	I	0.97	72	0.440	0.228	0.400
MAR 11	30	0.842	0.546	0.815	1.96	59	0.07	62	I	0.88	49	0.346	0.226	0.295
MAR 21	30	1.282	0.766	1.010	2.79	62	0.26	57	I	1.15	63	0.438	0.263	0.320
APR 1	30	0.829	0.622	0.710	2.25	62	0.00	49	I	1.25	62	0.395	0.287	0.395
APR 11	30	1.030	0.776	0.865	3.25	65	0.00	56	I	1.70	65	0.450	0.315	0.395
APR 21	30	1.231	0.897	0.985	3.29	70	0.00	52	I	1.96	51	0.546	0.512	0.360
MAY 1	30	1.131	1.091	0.935	5.55	64	0.04	58	I	2.55	64	0.517	0.463	0.425
MAY 11	30	0.814	0.596	0.820	2.29	70	0.04	73	I	2.21	70	0.406	0.399	0.385
MAY 21	30	1.006	1.101	0.725	5.42	53	0.00	63	I	1.73	53	0.461	0.427	0.330
JUN 1	30	1.422	1.671	0.745	8.09	64	0.05	60	I	7.31	64	0.809	1.336	0.375
JUN 11	30	1.160	1.553	0.760	8.40	75	0.00	61	I	3.70	75	0.590	0.709	0.400
JUN 21	30	0.957	0.984	0.705	4.65	69	0.00	64	I	2.10	69	0.547	0.539	0.325
JUL 1	30	0.654	0.720	0.390	2.78	78	0.00	70	I	1.11	78	0.303	0.266	0.240
JUL 11	30	0.557	0.632	0.515	3.29	72	0.00	73	I	1.55	72	0.323	0.336	0.240
JUL 21	30	0.301	0.350	0.160	1.24	62	0.00	74	I	0.85	75	0.233	0.266	0.140
AUG 1	30	0.525	0.621	0.235	2.00	72	0.00	75	I	2.00	72	0.347	0.466	0.140
AUG 11	30	0.487	0.696	0.195	2.93	68	0.00	71	I	1.20	68	0.245	0.292	0.170
AUG 21	30	0.844	0.705	0.605	2.54	75	0.00	69	I	1.12	51	0.383	0.270	0.360
SEP 1	30	0.672	0.613	0.500	2.52	59	0.00	58	I	1.05	65	0.396	0.318	0.320
SEP 11	30	0.807	0.735	0.585	3.05	68	0.00	74	I	1.18	68	0.417	0.298	0.425
SEP 21	30	0.839	0.773	0.750	2.99	51	0.00	66	I	1.40	54	0.412	0.341	0.350
OCT 1	30	0.859	0.623	0.700	3.11	55	0.00	78	I	1.45	55	0.434	0.398	0.340
OCT 11	30	0.915	0.837	0.760	3.05	51	0.00	74	I	1.18	51	0.405	0.322	0.360
OCT 21	30	1.093	0.806	0.975	2.95	51	0.00	58	I	1.55	51	0.483	0.350	0.435
NOV 1	29	1.046	1.016	0.700	3.60	74	0.05	69	I	1.50	74	0.484	0.366	0.400
NOV 11	29	1.557	0.893	1.750	3.41	78	0.20	72	I	2.35	78	0.668	0.510	0.650
NOV 21	29	1.734	0.909	1.650	3.20	64	0.00	56	I	1.35	55	0.667	0.371	0.700
DEC 1	29	1.578	1.028	1.320	4.24	68	0.14	69	I	2.25	68	0.631	0.474	0.500
DEC 11	30	1.451	0.918	1.165	4.31	71	0.20	65	I	1.37	71	0.542	0.331	0.500
DEC 21	30	1.947	1.226	1.855	5.23	49	0.14	59	I	1.80	64	0.640	0.404	0.550
MONTH									I					
JAN	30	5.770	3.314	4.635	14.00	53	1.66	55	I	2.95	53	1.039	0.616	0.835
FEB	30	4.096	1.909	3.635	8.37	61	1.30	69	I	2.50	61	0.853	0.494	0.700
MAR	30	3.289	1.267	3.255	7.03	74	1.38	58	I	1.15	63	0.606	0.243	0.600
APR	30	3.090	1.449	2.780	6.21	70	0.65	52	I	1.96	51	0.797	0.469	0.600
MAY	30	2.951	1.415	2.425	7.15	64	1.25	58	I	2.55	64	0.817	0.540	0.650
JUN	30	3.538	2.191	3.225	9.58	75	0.27	61	I	7.31	64	1.283	1.356	0.980
JUL	30	1.512	0.977	1.505	3.69	72	0.03	73	I	1.55	72	0.511	0.340	0.490
AUG	30	1.856	1.185	1.900	4.28	77	0.00	55	I	2.00	72	0.621	0.430	0.525
SEP	30	2.318	1.322	2.070	5.53	61	0.20	66	I	1.40	54	0.693	0.288	0.655
OCT	30	2.867	1.789	2.760	7.53	50	0.34	53	I	1.55	51	0.713	0.363	0.625
NOV	29	4.336	2.021	4.480	8.21	58	0.87	72	I	2.35	78	0.912	0.455	0.890
DEC	29	4.988	1.798	4.850	8.73	49	2.45	63	I	2.25	68	0.968	0.444	0.840

Table 22.--Frequency distribution of daily precipitation amounts at West Glacier, Polebridge, and Summit; based on years 1949-78

PRECIPITATION - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 248809 WEST GLACIER 1949-1978

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.00
JAN 1	299	589	458	328	191	110	64	43	27	13	7			
JAN 11	300	637	483	377	243	153	113	87	47	13	7			
JAN 21	330	585	448	358	224	133	73	52	33	18	9			
FEB 1	300	487	377	273	157	93	63	40	23	10	7	7	3	
FEB 11	300	540	417	290	167	90	63	50	27	20	7			
FEB 21	247	457	348	211	150	105	65	49	32	16	8			
MAR 1	300	420	310	233	103	60	33	23	10					
MAR 11	300	400	270	183	80	33	13	7	7	3				
MAR 21	330	427	327	239	130	64	36	15	3					
APR 1	300	337	233	157	80	37	10	7	7					
APR 11	300	393	267	197	107	60	33	23	20	7	3			
APR 21	300	390	253	200	123	70	50	23	10	7	7			
MAY 1	300	373	307	233	140	93	60	37	17	13	10	7		
MAY 11	300	377	277	217	150	80	57	33	17	10	7			
MAY 21	330	427	294	215	127	85	61	36	24	12	9			
JUN 1	300	437	320	257	170	110	83	63	40	33	23	10	7	3
JUN 11	300	423	287	200	140	113	83	47	23	17	10	3		
JUN 21	300	417	323	257	177	140	100	63	57	33	17	10		
JUL 1	300	310	230	197	137	83	73	57	43	27	7	3		
JUL 11	300	260	157	110	63	47	43	23	20	7	7			
JUL 21	330	206	148	106	55	27	18	18	9	6	6	3		
AUG 1	300	257	157	97	67	40	30	23	17	7				
AUG 11	300	230	157	127	87	67	57	37	27	7	3			
AUG 21	330	364	252	209	152	115	79	48	33	12	9	3		
SEP 1	300	293	233	180	113	83	60	37	23	7	3	3		
SEP 11	300	310	233	197	123	87	57	33	20	13	3	3		
SEP 21	300	340	263	210	163	100	63	30	23	7				
OCT 1	300	340	267	197	133	93	47	40	27	7	7	3		
OCT 11	300	370	300	207	117	80	57	33	23	13	10			
OCT 21	330	403	315	239	133	79	39	33	30	15	3	3		
NOV 1	300	400	290	210	133	93	67	47	33	17	3			
NOV 11	300	563	407	327	200	127	90	63	47	23	13			
NOV 21	300	520	410	327	190	123	80	50	37	17	13			
DEC 1	300	550	427	343	227	127	67	43	27	10	7			
DEC 11	300	580	470	340	210	137	90	50	27	7				
DEC 21	330	606	485	367	197	115	73	48	27	9	6	3	3	
MONTH														
JAN	929	603	463	354	220	132	83	60	36	15	8			
FEB	847	497	383	261	158	96	64	46	27	15	7	2	1	
MAR	930	416	303	219	105	53	28	15	6	1				
APR	900	373	251	184	103	56	31	18	12	4	3			
MAY	930	394	292	222	139	86	59	35	19	12	9	2		
JUN	900	426	310	238	162	121	89	58	40	28	17	8	2	1
JUL	930	257	177	137	84	52	44	32	24	13	6	2		
AUG	930	286	190	146	103	75	56	37	26	9	4	1		
SEP	900	314	243	196	133	90	60	33	22	9	2	2		
OCT	930	372	295	215	128	84	47	35	27	12	6	2		
NOV	900	494	369	288	174	114	79	53	39	19	10			
DEC	930	580	461	351	211	126	76	47	27	9	4	1	1	

(con.)

Table 22. (Con.)

PRECIPITATION - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 246615 POLEBRIDGE 1949-1978

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.00
JAN 1	290	528	407	300	179	90	59	34	10	7	3	3		
JAN 11	290	572	455	362	217	131	90	59	45	34	10			
JAN 21	319	517	404	292	176	91	47	31	22	13	3			
FEB 1	289	405	308	225	128	87	45	17	17	7	3			
FEB 11	290	455	345	238	121	52	45	38	24	10	3			
FEB 21	238	416	307	218	105	71	50	38	21	17				
MAR 1	290	434	307	200	83	55	24	14	10	7				
MAR 11	290	324	203	131	66	28	14	3	3	3				
MAR 21	319	404	248	182	85	38	31	16	6	3	3	3		
APR 1	290	317	217	155	66	31	21	7	3					
APR 11	290	376	259	152	66	38	21	17	3	3	3			
APR 21	290	369	255	193	103	59	28	14	3	3	3			
MAY 1	300	390	283	210	110	60	23	17	17	7				
MAY 11	300	317	230	193	100	50	27	23	13	10	7	3		
MAY 21	330	361	264	170	109	64	39	18	18	6	3			
JUN 1	300	377	283	203	123	83	60	47	37	20	17	7	3	
JUN 11	300	350	260	177	90	60	40	17	17	13				
JUN 21	300	387	277	217	157	83	60	50	27	13	10	7		
JUL 1	300	320	257	190	87	50	33	20	13	10	7			
JUL 11	300	243	173	117	73	33	27	20	7					
JUL 21	330	182	148	91	55	24	15	9	6	3				
AUG 1	300	213	170	120	60	40	33	20	13	7				
AUG 11	300	207	170	133	77	33	30	17	10	3				
AUG 21	330	300	233	173	94	52	33	27	24	15	6			
SEP 1	300	263	213	140	87	57	30	13	10					
SEP 11	300	283	220	160	97	33	27	17	10	3	3			
SEP 21	300	300	217	157	93	53	37	13	3					
OCT 1	300	310	240	150	97	73	33	27	17	3	3			
OCT 11	300	293	227	177	113	60	43	33	20	3				
OCT 21	330	379	297	221	103	61	45	18	9	6	3			
NOV 1	290	324	238	176	100	59	45	28	21	14	7			
NOV 11	290	483	376	276	148	76	62	45	31	14				
NOV 21	290	448	390	269	172	110	62	41	24	17	10			
DEC 1	300	470	367	280	183	110	67	50	13	7				
DEC 11	300	503	393	307	153	97	47	30	27	10	3			
DEC 21	330	509	403	291	176	130	67	33	21	6	3			
MONTH														
JAN	899	538	422	317	190	103	65	41	26	18	6	1		
FEB	817	426	321	228	119	70	47	31	21	11	2			
MAR	899	388	253	171	78	40	23	11	7	4	1	1		
APR	870	354	244	167	78	43	23	13	3	2	2			
MAY	930	356	259	190	106	58	30	19	16	8	3	1		
JUN	900	371	273	199	123	76	53	38	27	16	9	4	1	
JUL	930	246	191	131	71	35	25	16	9	4	2			
AUG	930	242	192	143	77	42	32	22	16	9	2			
SEP	900	282	217	152	92	48	31	14	8	1	1			
OCT	930	329	256	184	104	65	41	26	15	4	2			
NOV	870	418	334	240	140	82	56	38	25	15	6			
DEC	930	495	388	292	171	113	60	38	20	8	2			

(con.)

Table 22. (Con.)

PRECIPITATION - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 247978 SUMMIT 1949-1978

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.00
JAN 1	300	663	603	517	333	220	160	110	90	50	27	10	7	
JAN 11	300	697	637	507	357	243	193	137	103	60	27	10	3	
JAN 21	330	606	530	421	267	179	127	88	55	24	15	3		
FEB 1	300	537	497	413	263	180	123	83	43	20	13	3		
FEB 11	300	643	563	417	260	160	110	73	50	37	20	7	3	
FEB 21	247	543	498	393	263	186	138	97	61	24	8			
MAR 1	300	580	520	413	217	143	83	47	37	10				
MAR 11	300	500	467	297	143	90	53	30	20	3				
MAR 21	330	567	506	394	252	127	73	61	33	9	6			
APR 1	300	423	377	270	167	93	63	33	20	13	3			
APR 11	300	453	407	303	200	133	77	50	30	13	3	3		
APR 21	300	503	457	353	223	137	70	50	37	27	23	13		
MAY 1	300	450	403	313	187	133	83	50	43	23	10	7	7	
MAY 11	300	387	340	253	163	97	60	27	23	7	3	3	3	
MAY 21	330	388	355	224	152	100	67	55	39	21	18	8		
JUN 1	300	430	380	270	190	117	93	80	63	43	27	10	7	3
JUN 11	300	373	327	250	187	120	80	57	47	37	27	10	3	3
JUN 21	300	380	330	247	150	83	57	47	43	27	17	7	7	
JUL 1	300	293	253	200	133	87	50	33	17	10	3			
JUL 11	300	247	210	170	87	57	53	33	20	10	3	3		
JUL 21	329	146	116	85	46	24	18	18	16	3				
AUG 1	300	207	180	127	73	50	43	33	23	17	10	3	3	
AUG 11	300	240	207	147	103	53	33	23	13	10	7			
AUG 21	330	352	321	248	155	103	70	30	18	9	3			
SEP 1	300	287	257	193	113	67	63	43	27	20	3			
SEP 11	300	347	303	220	153	93	73	57	37	7	7			
SEP 21	300	340	310	237	163	123	70	40	30	13	7			
OCT 1	300	300	283	240	143	110	83	50	37	23	13			
OCT 11	300	357	330	273	167	117	83	53	40	10	3			
OCT 21	330	442	406	315	182	112	67	45	39	12	9	3		
NOV 1	290	400	352	276	186	124	93	69	45	28	14	3		
NOV 11	289	609	543	426	291	187	121	83	69	28	17	10	3	
NOV 21	290	600	541	434	317	221	155	114	83	41	24			
DEC 1	290	586	538	428	293	228	145	90	62	21	14	7	3	
DEC 11	300	600	560	450	257	180	113	73	53	20	17			
DEC 21	330	661	594	464	324	218	158	115	64	39	15	3		
MONTH														
JAN	930	654	588	480	317	213	159	111	82	44	23	8	3	
FEB	847	576	521	409	262	175	123	84	51	27	14	4	1	
MAR	930	549	498	369	205	120	70	46	30	8	2			
APR	900	460	413	309	197	121	70	44	29	18	10	6		
MAY	930	408	366	262	167	110	70	44	35	17	11	4	3	
JUN	900	394	346	256	176	107	77	61	51	36	23	9	6	2
JUL	929	226	191	150	87	55	40	28	18	8	2	1		
AUG	930	269	239	176	112	70	49	29	18	12	6	1	1	
SEP	900	324	290	217	143	94	69	47	31	13	4			
OCT	930	369	342	277	165	113	77	49	39	15	9	1		
NOV	869	536	479	379	265	177	123	89	66	32	18	5	1	
DEC	920	617	565	448	292	209	139	92	60	27	15	3	1	

Table 23.--Precipitation statistics (inches) for additional stations during fire season. Based on indicated years; 1951-80, where available

P R E C I P I T A T I O N BY 10 (OR 11)-DAY AND MONTHLY PERIODS

STATION NUMBER 240206 DESERT MTN L.O. YRS 1951-1970

PERIOD BEGINS	NO. YRS	10-DAY AND MONTHLY TOTALS MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT. YR	LOWEST TOT.YR	MAXIMUM DAILY TOTALS EXTREME	YR	AVG MAX	STD DEV	MEDIAN
JUL 1	15	.725	.765	.380	2.63 55	.04 60	1.22	64	.335	.347	.160
JUL 11	20	.347	.367	.190	1.09 70	.00 60	.70	70	.209	.207	.135
JUL 21	20	.364	.477	.095	1.50 70	.00 68	1.03	57	.232	.278	.075
AUG 1	20	.533	.747	.215	3.18 60	.00 66	2.40	60	.331	.537	.155
AUG 11	19	.202	.325	.030	1.16 54	.00 70	1.55	68	.098	.136	.030
AUG 21	16	.732	.741	.550	2.57 51	.00 55	1.75	54	.417	.381	.415
MONTH											
JUL	15	1.237	1.127	1.090	4.45 55	.09 60	1.22	64	.443	.365	.390
AUG	16	1.262	.874	1.265	3.04 56	.00 55	2.40	60	.509	.357	.535
JUL		1.44*									
AUG		1.47*									

STATION NUMBER 240217 HUNGRY HORSE R.S. YRS 1958-1980

PERIOD BEGINS	NO. YRS	10-DAY AND MONTHLY TOTALS MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT. YR	LOWEST TOT.YR	MAXIMUM DAILY TOTALS EXTREME	YR	AVG MAX	STD DEV	MEDIAN
MAY 1	18	.880	.712	.750	2.86 64	.02 66	1.52	64	.489	.359	.470
MAY 11	19	.857	.707	.710	2.21 71	.00 80	1.02	58	.445	.316	.500
MAY 21	17	1.137	1.056	.600	3.77 80	.00 58	1.77	68	.556	.541	.330
JUN 1	23	1.320	1.189	.940	5.26 66	.00 60	2.80	66	.703	.711	.440
JUN 11	23	.805	.664	.740	2.93 65	.01 77	1.10	65	.420	.300	.370
JUN 21	23	1.126	1.162	.950	4.12 63	.00 79	2.15	67	.582	.578	.440
JUL 1	23	.628	.516	.550	1.71 78	.00 68	.96	66	.342	.286	.320
JUL 11	23	.543	.641	.220	2.24 77	.00 73	.91	76	.293	.317	.180
JUL 21	23	.357	.511	.080	1.66 70	.00 80	1.25	77	.220	.324	.070
AUG 1	23	.441	.673	.110	3.02 60	.00 79	1.22	60	.255	.303	.110
AUG 11	23	.760	1.012	.260	3.38 78	.00 73	1.70	68	.413	.535	.120
AUG 21	23	.922	.804	.610	2.54 75	.00 69	1.24	71	.425	.332	.390
SEP 1	23	.803	.450	.750	1.69 61	.00 66	.88	80	.430	.242	.420
SEP 11	23	.801	.805	.480	3.45 68	.00 79	1.52	68	.479	.410	.330
SEP 21	21	.642	.619	.420	1.95 69	.00 79	.82	58	.280	.225	.230
MONTH											
MAY	17	2.817	1.027	2.790	4.57 78	1.40 63	1.77	68	.875	.441	.790
JUN	23	3.251	1.744	2.820	6.58 63	.60 77	2.80	66	.974	.733	.850
JUL	23	1.528	1.099	1.510	4.12 77	.04 60	1.25	77	.537	.343	.500
AUG	23	2.123	1.538	1.700	4.73 78	.05 69	1.70	68	.694	.463	.640
SEP	21	2.193	1.288	1.910	6.16 68	.46 66	1.52	68	.651	.318	.650

* SUM OF MEANS AVAILABLE FOR THE THREE 10 (OR 11)-DAY PERIODS

(con.)

Table 23. (Con.)

P R E C I P I T A T I O N BY 10 (OR 11)-DAY AND MONTHLY PERIODS

STATION NUMBER 240301 BELLY RIVER R.S. YRS 1951-1980

PERIOD BEGINS	NO. YRS	10-DAY AND MONTHLY TOTALS MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT. YR	LOWEST TOT.YR	MAXIMUM DAILY TOTALS EXTREME YR	AVG MAX	STD DEV	MEDIAN
JUN 21	13	1.202	1.307	.850	4.62 69	.00 61	2.14 69	.684	.694	.390
JUL 1	22	.637	.520	.430	1.83 56	.06 70	1.15 75	.365	.314	.245
JUL 11	28	.586	.736	.320	3.31 72	.00 51	1.55 72	.312	.389	.160
JUL 21	28	.480	.479	.325	1.96 58	.00 73	1.03 75	.293	.274	.210
AUG 1	28	.671	.710	.470	2.76 52	.00 55	1.52 76	.379	.372	.240
AUG 11	29	.648	.832	.260	3.08 66	.00 70	1.65 66	.340	.437	.150
AUG 21	29	.935	.975	.670	4.11 51	.00 70	1.55 79	.484	.466	.370
SEP 1	21	.891	.952	.580	3.02 65	.00 57	1.70 80	.477	.472	.370
MONTH										
JUL	22	1.579	1.082	1.410	4.04 58	.20 59	1.55 72	.483	.311	.420
AUG	28	2.311	1.457	1.905	5.14 77	.03 55	1.65 66	.797	.507	.635
JUL		1.70*								
AUG		2.25*								

STATION NUMBER 240303 ST MARY R.S. YRS 1951-1980

PERIOD BEGINS	NO. YRS	10-DAY AND MONTHLY TOTALS MEAN TOTAL	STD DEV	MEDIAN	HIGHEST TOT. YR	LOWEST TOT.YR	MAXIMUM DAILY TOTALS EXTREME YR	AVG MAX	STD DEV	MEDIAN
JUN 21	13	.657	.692	.550	2.14 55	.00 64	1.72 55	.442	.564	.300
JUL 1	24	.673	.779	.400	2.70 56	.01 67	1.98 56	.487	.599	.215
JUL 11	28	.445	.556	.205	2.32 72	.00 69	1.04 72	.227	.272	.080
JUL 21	28	.354	.437	.200	1.72 62	.00 80	1.15 75	.239	.297	.130
AUG 1	28	.529	.518	.355	1.80 56	.00 79	1.25 72	.322	.302	.265
AUG 11	28	.591	.742	.250	2.56 80	.00 70	1.20 80	.313	.370	.120
AUG 21	28	.686	.725	.380	3.00 51	.00 69	1.38 51	.375	.405	.220
SEP 1	19	.574	.533	.420	1.93 65	.00 57	1.02 65	.335	.291	.250
MONTH										
JUL	24	1.508	1.273	1.235	4.02 55	.02 67	1.98 56	.639	.570	.460
AUG	28	1.805	1.344	1.485	4.75 77	.00 55	1.38 51	.660	.394	.690
JUL		1.47*								
AUG		1.81*								

* SUM OF MEANS AVAILABLE FOR THE THREE 10 (OR 11)-DAY PERIODS

able 24.--Frequency distribution of daily precipitation amounts at stations as in table 25

PRECIPITATION - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT. DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN L.O. 1951-1970

ERIOD EGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.00
UL 1	168	351	256	220	131	77	60	36	30	24	12			
UL 11	200	235	160	115	60	40	20	10	10					
UL 21	220	191	127	86	55	45	41	14	9	5	5			
UG 1	200	255	195	140	70	55	40	25	10	5	5	5	5	
UG 11	196	173	122	82	46	20	15	5	5	5	5	5		
UG 21	192	349	260	214	130	99	73	47	26	16	16	5		
ONTH														
UL	588	252	175	134	78	53	39	19	15	9	5			
UG	588	259	192	145	82	58	43	26	14	9	9	5	2	

STATION NUMBER 240217 HUNGRY HORSE R.S. 1958-1980

RIOD GINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.00
AY 1	174	402	316	224	132	109	98	57	34	23	6	6		
AY 11	189	344	280	196	132	106	101	79	53	16	5			
AY 21	202	436	322	257	149	99	79	59	35	30	20	10		
JN 1	229	454	367	306	210	127	87	66	66	44	26	9	9	
JN 11	230	387	322	222	126	83	61	52	35	17	9			
JN 21	230	326	270	239	174	117	83	61	48	43	22	9	4	
JL 1	230	300	226	187	109	74	57	35	22	9				
JL 11	230	261	196	139	87	65	43	30	26	17				
JL 21	253	150	126	91	59	40	20	16	8	8	4			
IG 1	230	226	157	117	61	48	39	30	17	13	4			
IG 11	230	243	204	161	109	83	57	48	39	30	22	9		
IG 21	253	372	281	206	162	99	67	43	36	20	4			
P 1	230	322	274	243	161	104	61	52	26	9				
P 11	229	293	262	197	122	79	52	48	44	26	9	4		
P 21	213	362	291	230	150	94	56	28	19	5				
NTH														
Y	565	395	306	227	138	104	92	65	41	23	11	5		
N	689	389	319	255	170	109	77	60	49	35	19	6	4	
L	713	234	181	137	84	59	39	27	18	11	1			
G	713	283	216	163	112	77	55	41	31	21	10	3		
P	672	324	275	223	144	92	57	43	30	13	3	1		

(con.)

Table 24. (Con.)

PRECIPITATION - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240301 BELLY RIVER R.S. 1951-1980

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.(
JUN 21	150	380	287	240	147	113	80	60	53	40	33	7	7	
JUL 1	225	382	253	196	98	80	49	27	22	13	4			
JUL 11	279	312	222	168	97	57	32	22	18	14	7	4		
JUL 21	308	224	172	136	66	52	36	16	13	6	3			
AUG 1	280	311	236	179	118	64	43	39	29	11	7	4		
AUG 11	289	287	218	145	107	76	42	24	24	21	17	3		
AUG 21	319	395	276	191	132	100	63	38	28	19	16	9		
SEP 1	215	353	270	195	121	98	84	51	47	28	23	9		
MONTH														
JUL	812	298	212	164	86	62	38	21	17	11	5	1		
AUG	888	333	244	172	119	81	50	34	27	17	14	6		

STATION NUMBER 240303 ST MARY R.S. 1951-198(

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.01	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	3.(
JUN 21	143	322	245	154	98	56	21	21	21	21	21	7		
JUL 1	207	304	208	145	87	48	39	29	24	24	14	14		
JUL 11	269	257	193	100	63	41	30	15	15	4	4			
JUL 21	297	189	131	88	61	30	20	17	13	7	3			
AUG 1	278	263	191	144	97	72	40	22	18	11	4			
AUG 11	280	261	189	132	93	61	46	43	43	18	4			
AUG 21	308	318	233	153	91	55	42	29	26	16	10			
SEP 1	203	335	256	177	99	59	39	34	25	10	5			
MONTH														
JUL	773	243	173	107	69	39	28	19	17	10	6			
AUG	866	282	206	143	94	62	43	31	29	15	6			

Table 25.--Monthly and annual (seasonal) snowfall by individual years. M denotes amount missing, no estimate made. T denotes trace, amount too small to measure. E denotes amount partially or wholly estimated. Zero amounts not listed in early and late season. + denotes total incomplete due to missing data

Polebridge

Year	Snowfall											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Annual
	Inches												
1945-46		M	M	16.5	12.0	28.9	18.1	7.0	T	0.0			82.5+
46-47			2.5E	53.2	19.2E	19.2	3.5	17.7	.0	.0			115.3
47-48		T	.0	6.3E	11.0	14.9	28.2	17.4	15.4	T			93.5
48-49			T	31.3	46.0	20.3	32.0	11.1	.8	2.0	T		143.5
49-50		6.0E	8.2	3.2	60.9	66.4	15.5	9.8	2.0	T	M		172.0
1950-51		T	T	26.2E	19.4	51.4	23.2	23.0	10.8	2.0	T		156.0
51-52			16.5	2.5	58.2E	33.0	11.5E	2.0	.0	T			123.7
52-53			.0	1.3	34.8	26.7	21.3E	5.5	6.5	T			96.1
53-54			.0	7.8E	23.4E	91.2	17.0	28.0E	24.8	.0			192.2
54-55			T E	3.0	7.1	9.8	17.6	19.6	.1	.0			57.2
55-56			T	39.6	25.9	22.2	24.0	21.0E	4.5	8.7			145.9
56-57			5.0E	5.0E	29.7	39.3	39.3	6.5	.0	.0			124.8
57-58		.5E	13.3	5.5	41.5E	15.2E	20.8	7.1	T E	.0E			103.9
58-59		.0E	.0	36.2	25.5	50.8	34.5	1.7	1.5	1.0			151.2
59-60			4.3	47.1	4.5	18.9	14.5	14.5	4.0E	T E			107.8
1960-61			.0	14.7	17.1	7.2	25.6	6.4	9.9E	T E			80.9
61-62			12.4	22.4	37.9	15.3	8.9	12.4	1.5	.0			110.8
62-63			.0	4.3	12.0	16.2	9.3E	2.0E	1.0E	.0			44.8
63-64			.0	18.6	16.4	38.2	7.6	44.9	1.3	4.0E			131.0
64-65			.0	13.5E	55.3	40.3	21.0	10.1	5.0E	.0			146.7
65-66		2.5	.0	16.5	20.7	60.4	20.5	9.9	4.0	.0	8.3		142.8
66-67			3.0	22.8	15.0	39.0	17.9	17.4	1.0	1.0E			116.1
67-68			T E	M	27.0	M	M	M	M	T			M
68-69		T	1.0E	4.5	39.0	73.5	8.0	3.0	T	.0			129.0
69-70			5.0	3.5E	12.5E	42.0	9.0	10.0E	T E	1.0			83.0
1970-71			.5	30.0	43.9	61.0	15.1	23.5	1.0	2.0	4.8		181.8
71-72			6.0	18.8	68.7	76.1	26.6	10.3	8.0	.0			214.5
72-73		4.5	15.0	3.0	11.8	12.0	15.0	8.7	1.0	.0			71.0
73-74			T E	43.6	25.8	25.0	35.0	15.3	5.4	.0			150.1
74-75		T	.0	9.1	27.1	50.7	55.3	16.0	4.4	1.9			164.5
75-76			17.0	18.0	16.2	40.7	58.4	14.0	1.9	.0	T		166.2
76-77			2.0	2.6	7.8	8.8	4.0	17.0	3.5	.0			45.7
77-78			.0	11.0	34.5	24.0	16.0	5.0	2.0	2.0			94.5
78-79			T	9.0	20.9	13.6E	20.0	12.5	11.8	.0			87.8
79-80			2.0E	1.3	11.8	22.0E	20.0	16.0	.0	.0			73.1
1980-81			T	13.5	39.0	4.5	10.5	4.0	8.0	.0			79.5
81-82			T	17.0	21.5	58.5	12.0	13.5	16.0	.0			138.5
82-83			.0	24.5	29.0	11.5	5.5	9.0	4.3	.0			83.8
83-84			.0	12.3	23.9	17.5	9.0	7.0	4.0	T			73.7
84-85			14.5	12.5	35.5E	1.0	17.5	6.5	3.0	.0			89.5
85-86			3.3	17.0	6.0	(Data not available at publication time)							
10-year averages													
1951-60		.1	3.9	17.4	27.0	35.9	22.4	12.9	5.2	1.2	T		126.0
1961-70		.3	2.1	13.4	25.3	36.9	14.2	12.9	2.6	.6	.8		109.1
1971-80		.5	4.3	14.6	26.9	33.4	26.5	13.8	3.9	.6	.5		125.0

(con.)

Table 25. (Con.)

West Glacier, Park Headquarters

Year	Snowfall												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Annual
	- Inches -												
1920-21			1.8	1.4	13.8	30.0	17.0	27.3	2.0	M			93.3+
21-22		T	.0	42.0	17.5	43.0	21.0	8.0	6.0	M			137.5+
22-23			T	9.0	M	45.2	M	M	M	1.0			M
23-24			T	M	43.5	29.5	2.0	M	T	.0	6.0		M
24-25		M	M	24.0	53.2	63.3	12.5	16.5	M	M			169.5+
25-26		M	3.5	4.0	4.2	30.0	17.7	1.0	3.5	.0			63.9+
26-27		7.5	.0	21.0	28.5	53.2	41.5	7.5	2.0	M			161.2+
27-28			2.3	31.8	44.5	26.0	2.5	6.0	8.0	.0			121.1
28-29			T	1.5	29.5	32.8	42.5	12.5	4.7	1.0			124.5
29-30			T	1.0	51.8	19.8	14.0	2.0	.0	.0			88.6
1930-31			5.0	30.5	9.6	11.8	6.7	12.8	.0	.0			76.4
31-32			.0	15.0	29.4	29.3	26.3	20.8	.0	.0			120.8
32-33			3.5	30.5	38.0	37.7	43.6	14.7	8.5	.0			176.5
33-34			8.2	2.5	42.2	13.7	1.5	20.5	6.0	.0			94.6
34-35		T	1.0	1.0	39.1	54.0	2.8	14.0	5.5	.0			117.4
35-36			3.0	13.7	15.5	52.7	32.0	29.2	.0	.0			146.1
36-37			2.0	3.8	27.5	51.5	57.5	2.5	.0	.0			144.8
37-38		T	.0	9.0	16.7	9.9	26.1	5.5	T	T			67.2
38-39			.0	7.0	55.7	37.5	23.4	13.0	.0	.0			136.6
39-40			3.8	.0	2.2	15.7	31.8	.6	2.0	.0			56.1
1940-41			.0	26.3	14.5	41.0	3.5	.5	T	.0			85.6
41-42		T	.0	4.0	16.0	6.0	17.5	8.0	1.5	T			53.0
42-43			4.0	30.5	37.2	40.5	19.7	20.0	.0	0.5			152.4
43-44			2.5	2.0	10.5	6.2	11.4	13.6	.0	.0			46.2
44-45			.0	11.2	15.1	9.7	13.0	14.7	5.0	.0			68.7
45-46		.5	2.5	33.1	20.2	47.7	24.3	8.4	T	.0			136.7
46-47			.5	41.7	26.8	33.8	12.0	26.7	2.0	.0			143.5
47-48		T	.0	21.5	23.8	14.8	29.9	25.2	24.0	.0			139.2
48-49			.0	27.7	54.1	31.3	37.4	16.6	T	.0			167.1
49-50		1.0	T	2.7	73.1	66.4	25.1	27.5	2.5	T	T		198.3
1950-51			T	22.6	30.5	57.5	30.5	35.5	4.5	5.0	T		186.1
51-52			28.0	14.5	74.2	49.3	21.5	17.3	T	.0			204.8
52-53			.0	1.0	45.4	50.0	35.5	11.9	17.4	.0			161.2
53-54			.0	3.5	37.8	74.5	15.9	32.0	23.0	.0	T		186.7
54-55			.0	1.0	18.7	27.4	41.2	28.2	4.9	.0			121.4
55-56			1.5	24.5	35.7	37.5	47.0	15.5	9.0	5.0			175.7
56-57			3.5	8.5	32.3	64.5	53.8	11.5	.0	.0			174.1
57-58			3.5	11.0	36.3	30.0	30.5	10.0	.0	.0			121.3
58-59			T	29.0	39.5	50.0	40.5	9.5	3.0	.0			171.5
59-60			2.5	58.3	7.5	38.9	31.5	20.0	11.0	.0			169.7
1960-61			T	18.0	26.5	10.5	16.5	9.0	6.5	2.0			89.0
61-62		T	5.5	26.5	41.7	20.0	9.0	15.6	3.5	.0			121.8
62-63		T	.0	7.0	13.5	25.0	22.0	4.0	3.0	.0			74.5
63-64			.0	12.0	15.5	54.7	15.3	50.4	4.0	5.0			156.9
64-65			1.0	24.2	67.4	46.2	25.9	10.4	7.0	.5			182.6
65-66		3.2	.0	6.4	23.8	49.7	26.5	7.2	.5E	.0	8.0		125.3
66-67			1.0	22.1	29.6	36.8	22.5	13.0	1.5	1.3E			128.5
67-68			T E	10.8	33.0	31.0	5.0	3.0	T	.0			82.8
68-69		M	T	4.0	51.5	76.1	9.8	2.5	T	.0			143.9+
69-70			2.0E	3.5	14.5	55.7	20.0	21.0	T	2.0			118.7
1970-71			.0	27.0	71.0	57.3	19.5	15.5	.0	.0	1.5		191.8
71-72			1.0	24.0	95.0	93.0	43.0	22.0	1.0	.0			279.0
72-73		3.5E	10.0	4.0	21.0	17.5	16.5	9.0	3.0	T			85.0
73-74			T	51.0	33.0	35.0	34.0	11.0	1.0	.0			165.0
74-75			.0	7.0	32.0	53.0	41.0	10.0	7.0E	.0			150.0
75-76			7.0E	31.5	17.0	43.5	26.5	11.6	T	.0			137.6
76-77			.0	10.3	14.0	13.0	8.0	23.0	2.5	.0			70.8
77-78			T E	19.0	55.0	40.5	14.0	3.5	.5	1.5E			134.5
78-79			.0	14.0	49.6	35.5	29.0	16.0	10.0E	.0			154.1
79-80			.0	1.0	13.0E	29.0	25.0	22.0	.0	.0			90.0
1980-81			.0	3.0	41.5	8.5	13.0	4.0E	4.0E	T			74.0
81-82			.0	5.5E	29.0	74.5	30.0	9.0	7.0	.0			155.0
82-83			.0	31.0	48.0	14.5	9.0	2.5	2.0E	.0			107.0
83-84			.0	3.0	36.5	11.5	8.0	8.0	T	.0			67.0
84-85			15.0	22.0	65.5	2.0	26.0	12.0	3.0	T			145.5
85-86			4.0	20.0	20.0	(Data not available at publication time)							
10-year averages													
1921-30[1]		.9	.8	15.1	31.8	37.3	19.0	10.1	3.3	.3	.6		119.2
1931-40		T	2.7	12.3	27.6	31.4	25.2	13.4	2.2	T	.0		113.7
1941-50		.2	1.0	20.1	29.1	29.7	19.4	16.1	3.5	.1	T		119.1
1951-60		.0	3.9	17.4	35.8	48.0	34.8	19.1	7.3	1.0	T		167.3
1961-70		.3	1.0	13.5	31.7	40.6	17.3	13.6	2.6	1.2	.8		122.4
1971-80		.4	1.9	18.9	40.1	41.7	25.7	14.4	2.5	0.2	.2		145.8

(con.)

ıble 25. (Con.)

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ar	Snowfall											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Annual
	- Inches -											
35-36		0.0	8.5	12.7	11.7	88.0	58.3	53.7	11.1	0.0	0.0		244.0
36-37		2.0	11.4	9.6	76.5	36.4	80.6	17.0E	23.2	.0	.0		256.7
37-38		6.0	.0	31.1	61.7	35.5	48.6	53.0	13.7	28.5	T		278.1
38-39		.0	20.5	65.7	76.5	57.9	27.0	36.1	18.8	.0	.0		302.5
39-40		T	6.2	5.0	14.0	10.4	81.4	14.9	39.4	.0	.0		171.3
40-41		.0	6.0	47.2	19.4	37.5	14.3	10.9	2.5	5.5	.0		143.3
41-42		2.5	4.0	23.3	28.8	5.9	25.5	42.3	2.8	17.0	.0		152.1
42-43		6.0	17.7	70.1	47.5	70.8	60.3	41.0	14.0	25.0	16.5		368.9
43-44		7.0	12.6	9.7	12.5	24.7	30.3	41.5	1.5	5.0	.0		144.8
44-45		1.5	.0	39.3	33.9	33.0	38.3	41.3	65.3	M	M		274.8+
45-46		15.0	13.5	44.4	24.0	45.2	27.0	27.5	7.7	2.4	.0		206.7
46-47		T	30.8	76.9	54.4	38.2	38.4	50.5	12.6	T	T		301.8
47-48		17.0	1.0	28.7	21.5	43.6	53.7	60.8	34.8	11.0	.0	T	272.1
48-49		T	7.3	46.3	50.9	30.1	59.4	22.7	9.7	14.3	T		240.7
49-50		5.7	12.3	16.7	94.1	91.2	22.6	45.6	30.8	12.4	14.7		346.1
50-51		5.5	12.0E	51.9E	40.3E	77.3E	42.4	43.3E	26.3	25.5E	5.0		329.5
51-52		8.0	61.0	30.5	58.5	49.8	21.0	27.0	4.6	T	.0		260.4
52-53	0.5	.0	1.0	21.2	26.4	68.9	26.9	30.7	74.8	2.5	T		252.9
53-54		T	M	M	M	123.0	45.3E	66.0	87.0	4.0	.0		M
54-55		14.0	M	M	M	M	M	M	18.0	16.0	.0		M
55-56		.0	M	M	M	M	M	72.7	32.0	27.0	.0		M
56-57		.0	M	M	M	M	81.0E	20.0	26.0E	.0	.0		M
57-58		9.0	22.0	18.0	57.0	31.0	27.0	23.0	19.0	.0	.0		206.0
58-59		15.0	2.0	65.0	47.0	[2]65.0E	42.0	[2]32.0	22.0	6.0	T		296.0
59-60		6.0E	19.0E	67.0	18.0	[2]38.0	19.0	[2]32.0	42.0	14.0	.0		255.0
60-61		.0	4.0	39.0	25.0	27.0E	46.0	26.0	42.0	8.0	.0		217.0
61-62		29.0E	22.0	43.0	45.0E	19.0	20.0	42.0	12.0	4.0	T		236.0
62-63	T	10.5E	M	21.0E	38.0	32.0	18.0	23.0E	16.0E	5.0	M		
63-64		.0	M	M	M	M	M	M	M	M	.0		M
64-65	T	T	6.0	25.0	72.0	56.0	70.0	19.0	23.0	.5E	T		271.5
65-66		19.0	1.0E	36.0	33.0	55.0	22.0	21.0	8.0	5.0	10.0E		210.0
66-67		.0	11.0	42.0	29.0	25.0	24.0	17.0	20.0	14.0E	.0		182.0
67-68		0.5E	6.0	23.0E	43.3	26.0	11.5	17.2	18.0	3.0E	T		148.5
68-69		8.9	16.7	28.7E	71.4	104.4	14.5	27.8	5.5	2.5	3.0		283.4
69-70		.0	15.0	19.5	30.5	77.0	69.3	44.0	83.0	17.0	T		355.3
70-71		5.0	10.5	34.9	79.5	107.5	30.0E	59.8	15.0	11.0	2.5		355.7
71-72	T	1.5	20.0E	23.0E	86.0E	131.1	71.2E	31.5	15.9	8.0	.0	4.0	392.2
72-73		18.0	26.0E	8.5E	42.0	23.5	22.5	16.0	19.6	4.5	T		180.6
73-74		2.0	4.0	51.5	41.3	70.0E	67.5	62.5	22.5	10.0	.0		331.3
74-75		.5	6.0E	31.5	58.0	28.0	68.0	44.5	21.5	8.0	.0		266.0
75-76		.0	22.0	29.8	23.5	47.5	94.5	23.0	8.5	4.0	T		252.8
76-77		1.0	10.0	18.5	21.3	25.5	12.0	31.5	7.0E	2.0	.0		128.8
77-78		.0	5.0	51.0	76.5	63.5	21.5	13.5	18.0	16.0	.0		265.0
78-79		.0	13.5	50.0	84.0	48.5	90.5	22.0	21.5	M	M		330.0+
-year averages (available years)													
49-50		5.5	10.5	40.3	38.7	42.0	37.0	38.4	18.2	10.3	3.5	T	244.4
59-60	.1	5.8	19.5	42.3	41.2	64.7	38.1	38.5	35.2	9.5	.5		295.4
69-70	T	6.8	10.2	30.8	43.0	46.8	32.8	26.3	25.3	6.6	1.3		229.9
69-79	T	3.1	13.0	33.2	56.9	60.6	53.1	33.8	16.6	7.9	.3	0.5	279.0

(con.)

Table 25. (Con.)

East Glacier

Year	Snowfall											
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Annual
	- Inches -												
1949-50		M	M	M	81.7	78.9	6.0	21.5	21.0	3.0	M		M
1950-51		M	T	59.1	15.7	63.2	39.9	30.2	16.2	12.0	2.0E		238.3+
51-52	T	5.0	52.0	14.0	46.5	27.0	20.0	23.0	15.0	.0E	.0E		202.5
52-53		T	3.0	17.5	19.5	M	M	28.0	72.0	1.0	T		M
53-54		T	T	M	M	M	59.0	M	M	M	T		M
54-55		8.0	5.0	10.0	20.0	11.0	53.0	63.0	14.0	16.0	T		200.0
55-56		T	M	56.5	27.5	28.0	65.0	44.5	26.5	14.5	.0		262.5+
56-57		.0E	M	M	25.0	32.4	57.8	M	22.0	T	.0		M
57-58		10.0	20.4	8.7	40.8	14.8	19.6	15.9	9.9	.0	.0		140.1
58-59		1.0	1.8	59.9	27.9	36.3	38.6	22.7	24.9	3.6	.0		216.7
59-60		T	17.5	49.0	6.5	22.6	22.5	32.5	M	8.0	T		M
1960-61		T	2.0	10.1	14.5	11.5	45.5	21.1	25.0	3.0	.0		132.7
61-62		M	19.0	37.0	41.0	M	M	39.5	M	.0	.0		M
62-63		4.0	.0	22.0	37.0	19.0	2.0	20.0	14.0	T	.0		118.0
63-64		.0	1.0	24.0	23.0	49.0	20.0	44.0	20.0	13.0	.0		194.0
64-65	T	1.0	2.0	19.5	78.5	47.0	40.0	24.0	19.0	T	2.0		233.0
65-66		14.0	.0	25.0	28.0	73.5	20.0	9.0	14.0	T	2.0		185.5
66-67	T	.0	11.0	49.0	18.0	46.0	42.0	26.0	40.0	12.0	T		244.0
67-68		.0	7.0	23.0	32.0	27.0	7.0	15.0	20.0E	3.0	.0		134.0
68-69		8.0	3.0	4.5	72.5	102.0	12.0	13.0	3.0	T	1.0		219.0
69-70		.0	M	9.1	11.2	31.7	29.5	23.5	36.0	6.0	.0		147.0+
1970-71		3.8	7.0	31.0E	36.0	64.5	18.0E	46.0	7.5	1.0	T	T	214.8
71-72		2.0E	13.5	19.5	88.0	106.0	57.0	19.0	13.0	3.0	.0	T	321.0
72-73		12.0	15.0	2.0	28.0	8.0	16.0	11.0	18.5	.5	T		111.0
73-74		T	5.0	49.0	15.4	48.2	36.0	36.0	4.5	6.0	.0		200.1
74-75		2.0	3.0E	18.5	13.5	33.0	50.5	29.5	.0.0E	6.0	.0		176.0
75-76		.0	15.0	16.0	14.0	34.0	60.0	9.0E	20.0	1.0	T		169.0
76-77		.0	1.0	11.0	21.0	12.0	2.0	29.0	4.0	3.0	.0		83.0
77-78		.0	4.0	35.0	63.0	55.0	20.0	4.5	8.0	7.0	.5		197.0
78-79		T	10.0	60.0	49.0	15.0	46.0	32.0	40.0	9.0E	1.0		262.0
79-80		.0	8.0	4.5E	42.0	37.0	18.0	33.0	18.0	.0	2.0		162.5
1980-81		3.0	2.0	15.0	54.0	7.0	8.0	5.0	19.0	2.0	.0		115.0
81-82		.0	8.0	13.0	18.0	63.0	18.0	37.0	30.0	12.0	T		199.0
82-83		6.0	2.0	29.0	28.0	25.2	4.5	17.0	3.0	2.0	.0		116.7
83-84		9.0	.0	15.0	21.0	10.0	6.0	17.0E	5.5	3.5	.0		87.0
84-85		16.0	47.0	10.0	66.0	4.0	27.0	30.0	13.0E	T	.0		213.0
85-86		24.0	30.0	29.0	5.0	(Data not available at publication time)							
10-year averages (available years)													
1951-60	T	2.7	12.5	34.3	25.5	29.4	41.7	32.5	25.1	6.1	.2		210.0
1961-70	T	3.0	5.0	22.3	35.6	45.2	24.2	23.5	21.2	3.7	.5		184.2
1971-80		2.0	8.2	24.7	37.0	41.3	32.4	24.9	15.4	3.7	.4	T	190.0

[1] Generally 1 or 2 years missing; January complete.
[2] Adjusted for apparent error.

able 26.--Frequency distribution of daily snowfall amounts at West Glacier, Polebridge, and Summit; based on years 1949-78

SNOWFALL - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 248809 WEST GLACIER 1949-1978

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.5	1	2	4	6	8	10	12	16	20	24
JAN 1	290	490	438	300	145	72	31	21	7	3		
JAN 11	290	507	462	321	138	69	34	14	7	3		
JAN 21	319	461	389	266	119	56	31	13	6	3		
FEB 1	290	328	290	190	103	38	21	17	10	3		
FEB 11	289	367	318	197	66	24	10	3				
FEB 21	239	293	247	172	79	42	21	4	4			
MAR 1	290	300	269	159	52	17	14	7				
MAR 11	290	200	169	72	17	10						
MAR 21	319	172	144	97	38	22	13	6	3			
APR 1	290	52	38	38	21	10						
APR 11	290	55	48	28	14	10	3					
APR 21	290	41	38	17	3							
MAY 1	290	34	31	21	3							
MAY 11	290											
MAY 21	319											
JUN 1	290	3	3	3	3	3	3					
JUN 11	290											
JUN 21	290	3	3									
JUL 1	290											
JUL 11	290											
JUL 21	319											
AUG 1	290											
AUG 11	290											
AUG 21	319											
SEP 1	280											
SEP 11	280	4	4	4								
SEP 21	278	7	7	4								
OCT 1	289	7	7									
OCT 11	290	21	21	7	3	3	3	3	3			
OCT 21	312	67	67	26	10	3	3					
NOV 1	290	107	97	62	28	21	3					
NOV 11	290	241	203	138	52	28	10	7	3			
NOV 21	290	279	248	159	62	31	14	7	3			
DEC 1	299	398	348	258	110	43	30	7				
DEC 11	300	420	393	250	130	50	20	10	3			
DEC 21	330	462	412	273	130	61	18	6	3	3		
MONTH												
JAN	899	485	428	295	133	66	32	16	7	3		
FEB	818	331	287	187	83	34	17	9	5	1		
MAR	899	222	192	109	36	17	9	4	1			
APR	870	49	41	28	13	7	1					
MAY	899	11	10	7	1							
JUN	870	2	2	1	1	1	1					
JUL	899											
AUG	899											
SEP	838	4	4	2								
OCT	891	33	33	11	4	2	2	1	1			
NOV	870	209	183	120	47	26	9	5	2			
DEC	929	435	385	260	124	52	23	8	2	1		

(con.)

Table 26. (Con.)

SNOWFALL - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 246615 POLEBRIDGE 1949-1978

PERIOD BEGINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.5	1	2	4	6	8	10	12	16	20
JAN 1	290	397	314	217	117	79	34	17	10	3	
JAN 11	290	393	331	224	121	62	38	21	7	7	3
JAN 21	319	373	310	197	75	34	16	13	3		
FEB 1	290	272	231	155	66	41	28	14	3		
FEB 11	290	283	231	169	72	41	21	10	3		
FEB 21	237	228	177	105	25	17	8				
MAR 1	290	269	214	114	48	24	10	3			
MAR 11	290	145	121	55	34	3					
MAR 21	319	132	119	72	19	6	6	3	3	3	
APR 1	280	61	43	21	11						
APR 11	280	75	64	29	11	4	4				
APR 21	280	57	43	25	4						
MAY 1	286	28	21	17	3	3					
MAY 11	290	14	14								
MAY 21	317	6	6	3							
JUN 1	299	3	3	3	3	3	3				
JUN 11	299										
JUN 21	300	3	3	3	3						
JUL 1	290										
JUL 11	290										
JUL 21	319										
AUG 1	300										
AUG 11	300										
AUG 21	330										
SEP 1	299										
SEP 11	299	7	3	3							
SEP 21	298	7	7	3							
OCT 1	280	21	21	14	7	7	4				
OCT 11	277	22	22	14	11	4					
OCT 21	307	91	75	46	20	7					
NOV 1	270	107	85	63	30	4	4	4			
NOV 11	270	181	159	107	56	30	7				
NOV 21	270	252	219	148	70	30	19	7	4	4	
DEC 1	300	317	273	170	80	37	27	10	3		
DEC 11	300	340	270	147	57	27	17	10	7	3	
DEC 21	329	340	267	170	88	43	15	9	6		
MONTH											
JAN	899	387	318	212	103	58	29	17	7	3	1
FEB	817	263	215	146	56	34	20	9	2		
MAR	899	180	150	80	33	11	6	2	1	1	
APR	840	64	50	25	8	1	1				
MAY	893	16	13	7	1	1					
JUN	898	2	2	2	2	1	1				
JUL	899										
AUG	930										
SEP	896	4	3	2							
OCT	864	46	41	25	13	6	1				
NOV	810	180	154	106	52	21	10	4	1	1	
DEC	929	333	270	163	75	36	19	10	5	1	

able 26. (Con.)

SNOWFALL - PERCENT FREQUENCY OF DAILY AMOUNTS (INCHES)

- GIVEN TO NEAREST TENTH PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 247978 SUMMIT 1949-1978

RIOD GINS	TOTAL NUM. DAYS	AMOUNT EQUAL TO OR GREATER THAN 0.5	1	2	4	6	8	10	12	16	20	24
N 1	249	558	518	353	193	96	72	44	32	24	12	
N 11	242	550	492	351	169	95	50	37	17	8	4	4
N 21	264	473	409	277	125	72	49	30	27	8	4	
B 1	269	416	398	253	138	74	33	19	7	4		
B 11	262	469	416	279	137	76	46	34	23	8	4	
B 21	219	365	329	205	128	73	46	18	14			
R 1	279	444	416	262	122	43	18	7	7			
R 11	275	378	320	193	65	22	4	4				
R 21	306	353	314	219	105	52	23	20	13	10		
R 1	290	255	228	141	66	41	31	17	10	3		
R 11	290	259	248	166	66	28	21	17	14	7		
R 21	289	277	246	152	80	55	31	21	17	14		
Y 1	290	141	121	72	34	14	7	3	3	3		
Y 11	290	110	93	59	28	10	3	3	3	3		
Y 21	319	41	34	34	22	6	3					
N 1	300	17	17	13	10	7	7	3				
N 11	300	3	3	3								
N 21	300	7	7	7								
L 1	300											
L 11	300	3	3	3	3							
L 21	329											
G 1	300											
G 11	300											
G 21	330	3										
P 1	298	27	20	13	7							
P 11	298	64	47	30	20	13	7	3	3			
P 21	297	71	67	61	27	17	7	3				
T 1	266	109	98	53	23	4	4	4				
T 11	264	136	121	83	34							
T 21	283	194	163	106	49	21	11	7	4	4	4	4
V 1	250	232	208	164	64	28	16	16				
V 11	249	418	369	233	108	56	16	8	4	4		
V 21	249	462	434	297	129	80	36	20	16	4	4	
C 1	250	472	432	292	144	60	32	28	16	4		
C 11	250	436	412	288	128	64	24	16	16			
C 21	275	535	491	371	182	105	65	40	18	4		
NTH												
JN	755	526	472	326	162	87	57	37	25	13	7	1
FB	750	420	384	248	135	75	41	24	15	4	1	
MR	860	391	349	224	98	40	15	10	7	3		
AR	869	264	241	153	70	41	28	18	14	8		
MY	899	96	81	55	28	10	4	2	2	2		
JN	900	9	9	8	3	2	2	1				
JL	929	1	1	1	1							
AG	930	1										
SP	893	54	45	35	18	10	4	2	1			
OT	813	148	128	81	36	9	5	4	1	1	1	1
NV	748	370	337	231	100	55	23	15	7	3	1	
DC	775	483	446	319	152	77	41	28	17	3		

Table 27.--Snowpack data. Average (Avg.) snow depth (SN), water content (WC), and density (DS, equal to WC/SN) on about first day of month, at snow-survey courses in or near Glacier National Park; based on or adjusted to 30-year period 1951-80. SN and WC are in inches. Maximum (Max.) and minimum (Min.) values observed during 1941-85, except as noted. A denotes averages adjusted from short record, 8 to 14 years of data; E, estimated value; dotted line, data unavailable. Letters in parentheses are snow course identifiers used in figure 2

Name of course, elevation, ft		Jan.1 SN	Jan.1 WC	Jan.1 DS	Feb.1 SN	Feb.1 WC	Feb.1 DS	Mar.1 SN	Mar.1 WC	Mar.1 DS	Apr. 1 SN	Apr. 1 WC	Apr. 1 DS	May 1 SN	May 1 WC	May 1 DS	
Cattle Queen 4,700 (CQ)	Avg.	. . . . .			. . . . .			87	27.0	0.31	87	30.5	0.35	. . . . .			
Desert Mtn. 5,600 (DM)	Avg.	28	6.7	0.25	40	11.0	0.28	47	14.2	0.31	48	16.7	0.35	35	14.2	0.40	
	Max.	50E	12.8E		55	17.2		66	21.7		70	23.3		51	22.8		
	Min.	15	2.7		21	5.2		27	7.0		22	7.4		0	.0		
Emery Creek 4,350	Avg. A	30	7.3	0.24	45	12.2	0.27	49	15.4	0.31	46	16.4	0.35	23	9.5	0.41	
Flattop Mtn.[1] 6,300	Avg. A		23.0			34.0			42.0			49.0			53.0		
	Max.		28.0			45.0						70.0			74.0		
Hell Roaring Div.[2] 5,770 (HR)	Avg.	52	14.4	0.28	72	22.9	0.32	82	28.0	0.34	86	32.8	0.38	72	32.0	0.44	
	Max.	78	22.2		105	34.9		115	43.3		116	48.6		102	48.0		
	Min.	28	5.8		38	10.5		57	15.5		60	18.8		35	13.1		
Hudson Bay Div. 5,800 (HB)	Avg. A	. . . . .			. . . . .			50	15.8	0.32	54	18.2	0.34	50	19.0	0.38	
Iceberg Lake 5,600 (IB)	Avg.	. . . . .			. . . . .			. . . . .			. . . . .			.69	31.8	0.47	(21.9)[3]
	Max.													116	52.6		
	Min.													10	2.1		
Josephine Lower 4,900 (JL)	Avg.	. . . . .			. . . . .			. . . . .			. . . . .			.44	17.9	0.39	
Kishenehn 3,890 (KS) (extremes 1951-85)	Avg.	. . . . .			. . . . .			33	8.8	0.27	29	8.9	0.30	. . . . .			
	Max.							54	15.7		67	18.3					
	Min.							9	1.4		8	1.4					
Many Glacier 4,900	Avg.[4] A	. . . . .			52	14.7	0.28	61	19.0	0.31	63	22.0	0.35	41	17.0	0.41	
Marias Pass 5,250 (MP)	Avg.	30	7.4	0.25	45	12.4	0.28	53	16.5	0.31	55	19.1	0.35	44	17.3	0.40	
	Max.	58	15.1		76	21.5		77	26.8		84	31.1		94	34.6		
	Min.	13	2.8		14	3.4		18	4.3		16	6.3		0	.0		
Mineral Creek 4,000 (MN)	Avg.	. . . . .			. . . . .			60	18.1	0.30	57	20.3	0.36	31	12.8	0.42	
Mount Allen 5,700 (MA)	Avg.	. . . . .			. . . . .			. . . . .			. . . . .			106	48.1	0.46	(39.3)[3]
	Max.	. . . . .			. . . . .			. . . . .			. . . . .			169	72.9		
	Min.	. . . . .			. . . . .			. . . . .			. . . . .			39	16.5		
Piegan Pass 5,500 (PG)	Avg.	. . . . .			. . . . .			. . . . .			. . . . .			89	41.1	0.46	(31.2)[3]
	Max.													146	65.8		
	Min.													13	5.7		
Ptarmigan 5,800 (PT)	Avg.	. . . . .			. . . . .			. . . . .			. . . . .			88	40.1	0.46	
	Max.													137	63.7		
	Min.													19	5.7		

[1]Data from snow pillow; WC only.
[2]January and February data are based on period beginning 1964. March extremes are for 1951-85; April and May extremes for 1942-85.
[3]Number in parentheses is 1922-50 average WC; average SN was about 20 inches below 1951-80 value.
[4]Insufficient data for January 1. WC from snow pillow averages about 10 percent less than values shown; larger difference on May 1.

able 28.--Monthly average temperatures based on 24-hour periods ending at indicated observation times (m.s.t.)[1]; based on or adjusted to 30-year normal period, 1951-80. Stations in Montana except as noted in Alberta (AB). Blanks denote insufficient data

tation, bserv. time		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		°F												
abb 6NE	Max.	28.7	35.7	38.9	49.4	60.1	67.6	75.8	74.6	65.9	56.3	42.0	34.3	52.4
6 p.m.	Min.	4.8	11.9	15.7	25.8	34.2	40.1	43.5	42.7	36.0	29.9	19.3	11.8	26.3
	Mean	16.8	23.8	27.3	37.6	47.2	53.9	59.7	58.7	51.0	43.1	30.7	23.1	39.4
rowning	Max.	26.4	33.4	37.4	48.9	59.9	67.8	77.2	75.6	66.4	55.7	39.8	31.9	51.7
5 p.m.	Min.	6.9	14.1	17.5	27.4	36.2	42.9	47.2	46.1	39.3	32.8	21.2	14.3	28.8
(midnight	Mean	16.7	23.8	27.5	38.2	48.1	55.4	62.2	60.9	52.9	44.3	30.5	23.1	40.3
beg. 1977)														
aldwell, AB	Max.	24.8	32.9	36.1	46.8	58.6	66.0	73.9	71.6	63.0	53.1	39.0	31.5	49.8
	Min.	6.3	15.3	17.8	27.3	36.7	43.5	48.0	46.2	40.1	33.4	21.9	14.4	29.2
	Mean	15.6	24.1	27.0	37.1	47.7	54.8	61.0	58.9	51.6	43.3	30.5	23.0	39.5
irway, AB	Max.	26.2	32.7	35.4	46.6	57.9	65.1	73.4	72.0	63.0	53.6	39.7	32.2	49.8
	Min.	6.1	13.3	16.2	26.6	36.0	42.3	46.8	46.0	38.8	31.8	20.1	12.7	28.1
	Mean	16.2	23.0	25.8	36.6	47.0	53.7	60.1	59.0	50.9	42.7	29.9	22.5	39.0
ssex	Max.	26.4	34.0	40.2	50.2	62.5	71.3	81.2	79.0	66.5	52.5	36.1	29.4	52.4
5 p.m.	Min.	11.5	17.0	19.5	27.6	34.2	41.0	45.2	44.3	37.3	29.8	21.9	16.8	28.9
	Mean	19.0	25.5	29.9	38.8	48.4	56.2	63.2	61.7	51.9	41.2	29.0	23.1	40.7
ngry Horse[2]	Max.	27.7	35.2	41.1	51.3	62.8	70.7	80.0	78.3	65.9	52.7	37.6	32.6	53.0
)am, 9 a.m.	Min.	14.7	18.9	21.7	30.7	39.1	45.5	49.4	48.6	40.7	33.0	25.4	20.5	32.4
	Mean	21.2	27.1	31.4	41.0	51.0	58.1	64.7	63.5	53.3	42.9	31.5	26.6	42.7
lispell AP	Max.	27.4	35.0	42.1	54.6	64.8	72.1	82.1	80.3	69.2	55.3	39.0	31.5	54.4
idnight	Min.	11.2	17.5	21.6	30.5	38.1	44.5	47.9	46.7	38.6	29.6	22.7	16.9	30.5
	Mean	19.3	26.3	31.9	42.6	51.5	58.3	65.0	63.5	53.9	42.5	30.9	24.2	42.5
ny Glacier	Max.	25.5	31.5	34.3	43.8	54.6	62.5	71.0	69.7	59.6	49.7	35.7	30.0	47.3
near hotel)	Min.	7.4	15.3	17.9	27.4	35.2	41.6	47.3	46.5	39.0	32.4	21.4	14.3	28.8
-7 p.m.	Mean	16.5	23.4	26.1	35.6	44.9	52.1	59.2	58.1	49.3	41.1	28.6	22.2	38.1
ny Glacier	Max.							73.5	72.0	61.7				
anger Stn.	Min.							42.5	41.6	36.3				
p.m.	Mean							58.0	56.8	49.0				
lebridge	Max.	27.4	36.2	41.7	52.3	63.5	71.1	80.2	78.8	68.7	54.8	37.9	30.4	53.6
p.m. (7 a.m.	Min.	6.8	12.7	16.2	25.2	32.1	38.5	40.8	39.1	33.0	25.9	18.9	12.3	25.1
eg. 1975)	Mean	17.1	24.5	29.0	38.8	47.8	54.8	60.5	59.0	50.9	40.4	28.4	21.4	39.4
mmit	Max.	22.7	29.6	33.7	44.1	55.2	63.7	72.6	70.9	60.3	48.5	33.1	26.5	46.7
p.m. (varied)	Min.	6.5	13.0	14.4	23.2	30.6	37.3	41.0	39.9	34.3	28.6	18.8	12.6	25.0
	Mean	14.6	21.3	24.1	33.7	42.9	50.5	56.8	55.4	47.3	38.6	26.0	19.6	35.9
SL[3] Hqtrs.	Max.	21.8	29.4	34.6	44.5	54.5	63.1	72.2	69.8	59.0	46.9	31.5	25.6	46.1
Stn. 1B)	Min.	5.9	12.8	15.5	23.8	30.8	37.6	43.2	42.2	35.5	28.7	18.2	12.1	25.5
idnight	Mean	13.9	21.1	25.1	34.2	42.7	50.4	57.7	56.0	47.3	37.8	24.9	18.9	35.8
SL Stn. 10	Max.	20.0	25.9	29.7	38.6	48.0	56.5	65.5	63.2	52.7	42.2	28.2	23.2	41.1
idnight[4]	Min.	8.7	12.5	14.0	21.6	29.4	36.3	46.0	45.0	36.6	28.1	17.5	14.0	25.8
	Mean	14.4	19.2	21.9	30.1	38.7	46.4	55.8	54.1	44.7	35.2	22.9	18.6	33.5
terton Park,	Max.	25.1	31.9	35.0	45.2	56.8	64.6	72.4	70.3	60.4	51.0	37.6	31.0	48.4
ameron Falls,	Min.	8.8	15.0	17.5	28.0	36.5	43.4	48.4	47.5	40.6	34.3	23.1	16.3	29.9
B[5]	Mean	17.0	23.5	26.3	36.6	46.7	54.0	60.4	58.9	50.5	42.7	30.4	23.7	39.2
meron Lake,[6]	Max.	18.8	26.8	29.8	39.7	49.8	59.3	68.9	66.6	56.8	46.0	31.6	24.3	43.2
aterton NP	Min.	4.4	10.8	13.1	22.8	30.9	37.9	42.8	42.3	35.5	29.8	19.0	11.7	25.1
	Mean	11.6	18.8	21.5	31.3	40.4	48.6	55.9	54.0	46.2	37.9	25.3	18.0	34.2
terton River	Max.	27.0	33.6	36.3	47.1	58.3	65.7	73.8	72.0	62.6	53.4	39.7	33.1	50.2
abin, AB	Min.	6.4	13.3	16.3	27.0	36.0	42.4	45.7	44.4	38.1	32.7	21.4	14.2	28.2
	Mean	16.7	23.5	26.3	37.1	47.2	54.1	59.8	58.2	50.4	43.1	30.6	23.7	39.2
st Glacier	Max.	27.6	34.8	41.0	52.1	63.7	70.9	79.6	77.6	66.4	52.9	37.5	30.8	52.9
p.m.	Min.	13.4	18.9	21.6	29.1	36.5	43.2	46.6	45.8	38.8	31.7	24.4	19.0	30.7
	Mean	20.5	26.9	31.3	40.6	50.1	57.1	63.1	61.7	52.6	42.3	31.0	25.0	41.8

[1] At Canadian stations, 24-hour maximum temperature is read in morning; minimum, about 5 or 6 p.m.
[2] Observation time beginning in 1968; normals estimated from 1968-82 data comparisons.
[3] Former Upper Columbia Snow Laboratory, near Marias Pass.
[4] Based on data from hygrothermograph; 1.0 degree added to average maximum and 1.0 degree subtracted from average minimum--as overall correction for typical instrument lag.
[5] At townsite, about one-fourth mile from former Headquarters Station.
[6] Based on data from hygrothermograph; no adjustment for possible instrument lag.

Table 29.--Monthly average daily maximum and minimum temperatures by individual years; based on 24-hour period ending at indicated observation time (m.s.t.). Some averages, particularly at Polebridge and Summit, may differ from originally published values; estimates have been made for missing days and a few apparent errors corrected. E denotes average estimated in whole or in large part (more than 10 days data were missing). M denotes missing, no estimate made

West Glacier - Observation time 5 p.m.

Year		Average daily maximum and minimum temperatures												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		°F												
1931	Max.	35.0	35.8	43.8	57.5	67.5	74.0	81.4	82.5	65.3	56.2	35.9	32.7	55.6
	Min.	20.9	18.3	22.0	28.2	36.5	44.1	45.7	42.9	40.4	28.9	19.4	17.7	30.4
1932		27.2	33.3	36.2	53.4	65.5	73.1	81.2	80.0	69.3	51.0	41.0	26.8	53.2
		13.4	14.4	17.7	29.2	36.0	44.1	44.9	46.4	35.0	31.9	26.9	10.5	29.2
1933		30.9	26.1	42.9	52.9	60.9	75.7	82.6	80.3	62.3	54.4	43.8	35.6	54.0
		11.3	11.0	25.2	28.8	34.9	42.3	45.0	43.9	38.1	32.3	29.0	22.6	30.4
1934		37.0	38.8	46.7	63.8	70.7	71.3	82.3	83.1	63.1	55.2	42.3	33.0	57.3
		24.0	20.9	26.7	32.6	40.2	43.9	47.6	44.9	37.5	34.5	32.1	22.2	33.9
1935		27.6	34.7	38.9	48.7	63.7	71.5	80.3	78.4	71.2	54.3	34.9	31.3	53.0
		13.4	15.0	21.0	22.7	33.4	41.0	46.8	42.9	38.5	28.5	19.5	22.5	28.8
1936		31.0	15.1	40.2	54.6	71.9	74.8	87.3	82.3	66.6	57.8	34.6	32.0	54.0
		19.9	-7.5	20.8	26.6	40.3	46.8	50.0	46.9	39.6	30.9	17.9	20.4	29.4
1937		9.2	29.7	42.9	51.0	66.4	71.4	80.3	73.8	68.8	52.8	37.4	30.2	51.2
		-7.0	11.9	22.2	31.3	37.6	44.3	49.6	46.0	41.5	36.6	27.2	21.3	30.2
1938		29.4	30.2	40.8	53.5	60.3	70.9	77.3	75.3	75.2	55.8	35.6	32.5	53.1
		18.5	14.3	26.6	31.0	38.3	45.9	50.2	45.7	43.0	35.7	23.5	20.1	32.7
1939		34.7	28.1	43.4	58.2	67.3	66.6	82.0	82.4	69.5	56.5	42.9	37.0	55.7
		23.6	11.5	22.5	32.0	39.0	43.4	48.3	44.3	41.2	32.8	25.3	24.3	32.4
1940		28.4	35.3	47.8	54.8	69.7	76.8	82.9	83.3	72.5	55.3	32.0	32.4	55.9
		13.8	23.6	29.5	32.9	39.2	45.0	50.3	44.9	47.1	37.6	17.7	23.1	29.5
1941		31.3	38.6	49.7	61.0	64.6	72.7	83.4	78.8	57.8	51.5	42.3	33.8	55.5
		18.5	18.6	24.0	31.2	39.8	46.3	51.3	48.9	40.1	31.8	27.8	21.7	33.3
1942		26.3	32.2	44.4	59.1	61.6	65.2	81.3	80.6	68.8	56.3	36.3	34.1	53.9
		12.5	16.0	24.3	30.7	37.6	45.1	48.6	47.1	41.0	33.2	21.8	22.2	31.7
1943		21.2	37.0	36.4	58.8	59.9	65.2	79.5	79.1	72.0	56.6	39.8	29.6	52.9
		7.5	17.4	12.7	32.0	35.7	41.0	46.6	45.0	37.7	33.9	26.2	19.7	29.6
1944		31.9	34.3	39.2	59.1	66.8	70.8	80.8	77.4	70.4	61.3	39.1	28.5	55.0
		16.0	18.1	18.5	30.0	38.9	45.5	46.2	44.5	40.1	31.8	28.7	17.0	31.3
1945		33.4	36.6	42.3	48.9	65.4	68.2	83.4	84.5	63.2	56.0	36.1	30.9	54.1
		21.2	20.1	23.4	28.9	37.5	43.5	47.5	45.9	38.8	32.8	24.2	21.3	32.1
1946		33.6	35.9	45.5	56.1	64.5	69.1	81.5	79.2	64.7	46.7	33.1	30.8	53.4
		21.0	22.9	27.5	31.2	36.1	42.2	47.3	45.5	39.6	30.3	19.9	16.7	31.7
1947		27.7	35.6	43.2	55.8	67.5	65.5	83.3	76.9	64.5	53.7	35.8	34.0	53.6
		13.3	14.6	22.4	31.0	38.7	44.2	47.2	45.5	41.9	38.4	24.9	21.1	31.9
1948		32.2	31.0	37.7	51.6	63.2	72.4	74.6	75.4	68.6	54.0	41.1	25.1	52.2
		15.8	13.4	15.9	29.6	39.5	47.1	45.4	46.2	37.8	27.7	31.2	10.5	30.6
1949		16.3	287.7	40.7	58.7	67.6	71.0	78.4	81.4	68.3	48.3	42.7	31.0	52.8
		-5.2	9.3	17.5	29.8	37.3	41.5	46.6	44.7	37.1	30.1	29.4	15.6	27.1
1950		13.9	34.6	37.6	48.6	61.3	68.5	78.5	77.3	68.1	52.5	37.1	33.7	51.0
		-4.2	17.5	21.7	28.8	34.5	41.7	47.4	45.5	37.3	34.7	23.0	23.8	29.1
1951		26.3	33.1	35.1	55.0	63.0	65.4	80.4	74.8	61.1	45.6	35.5	23.1	49.9
		11.0	13.6	13.9	24.0	35.2	39.8	46.4	45.4	36.6	33.1	23.8	10.3	27.1
1952		25.4	35.3	41.5	60.0	64.7	69.0	77.5	77.8	71.6	60.9	38.8	31.6	54.5
		11.1	19.4	20.5	27.9	38.1	43.8	45.2	46.0	39.7	30.4	23.8	22.7	30.
1953		37.0	36.8	44.5	48.6	62.4	67.3	82.1	78.8	70.2	59.8	42.1	34.7	55.4
		27.1	23.3	25.3	28.9	35.3	42.9	45.6	45.9	39.6	30.9	28.5	24.2	33.
1954		27.4	39.7	37.6	44.8	64.5	64.7	78.9	72.9	63.3	50.0	42.5	32.8	51.6
		11.7	23.9	16.1	26.7	36.2	41.9	45.8	46.0	40.0	30.0	31.4	22.7	31.
1955		31.2	29.4	33.0	46.2	58.4	72.2	74.2	80.6	66.2	51.8	28.6	28.8	50.1
		20.1	14.0	14.0	28.5	33.8	43.4	48.3	42.1	38.0	33.5	15.6	14.5	28.
1956		28.9	29.4	39.6	52.5	64.8	71.3	80.1	76.4	67.7	50.3	36.3	33.0	52.5
		16.4	12.8	21.9	27.3	37.4	42.6	48.3	46.0	39.9	34.5	24.7	19.0	30.
1957		17.5	32.3	41.5	51.9	68.3	70.3	79.7	76.2	70.9	47.9	38.2	35.8	52.5
		1.0	13.3	21.1	29.4	39.7	44.7	46.1	45.4	37.0	31.2	23.8	24.6	29.
1958		32.5	35.4	41.6	51.4	74.6	71.7	77.5	83.5	66.6	54.3	36.3	32.6	54.8
		21.7	22.1	22.2	31.3	40.3	46.5	48.4	49.5	39.9	30.5	23.6	22.2	33.
1959		28.6	29.7	42.4	53.5	58.9	71.3	81.4	73.4	59.8	49.3	32.5	32.9	51.1
		15.9	14.7	25.8	29.4	33.9	42.6	44.1	43.9	41.0	32.3	15.7	18.9	29.
1960		25.9	32.9	41.1	51.8	60.6	71.3	84.4	70.2	67.8	53.1	35.4	27.3	51.8
		10.7	15.0	19.8	29.3	35.3	42.2	47.8	45.5	38.0	32.4	25.0	18.5	30.

(con

Table 29. (Con.)

Year	Average daily maximum and minimum temperatures												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	°F												
1961	31.2	37.9	43.0	47.3	61.9	79.7	81.1	84.6	59.7	49.7	34.1	28.6	53.2
	18.4	27.7	26.2	30.1	38.2	45.4	48.5	48.1	35.3	30.5	19.7	16.1	32.0
1962	26.8	32.5	39.9	57.2	60.6	72.7	77.4	75.5	67.7	53.0	41.4	35.7	53.4
	9.6	16.4	19.3	29.4	38.0	41.4	45.2	45.7	36.7	34.6	30.7	25.4	31.0
1963	19.3	40.1	45.1	54.3	63.9	69.5	77.5	79.3	71.7	56.9	40.4	29.7	54.0
	3.6	23.1	25.3	30.5	35.4	45.0	45.9	47.1	42.6	35.1	27.3	17.7	31.6
1964	32.4	36.0	37.3	49.3	61.4	67.3	78.7	70.2	60.3	52.7	38.0	26.3	50.9
	22.5	19.4	20.2	28.9	36.2	43.4	46.7	43.1	37.4	35.7	25.1	14.2	30.7
1965	32.9	34.6	37.1	53.3	61.3	68.2	79.5	76.3	53.9	57.7	40.5	33.9	52.5
	24.0	18.7	12.9	29.7	34.4	42.1	43.9	47.3	34.6	34.8	27.9	22.1	31.0
1966	30.3	35.1	43.2	51.9	68.9	68.3	80.1	78.5	75.0	52.4	37.4	33.0	54.7
	17.1	16.3	21.1	28.6	36.0	42.3	44.6	42.5	42.0	31.9	24.2	23.6	30.8
1967	33.7	38.1	38.0	48.5	63.5	72.8	84.9	87.4	80.1	54.6	38.0	28.0	55.6
	22.6	23.2	20.6	27.3	36.1	43.1	45.8	46.1	43.3	32.4	25.3	17.0	31.9
1968	29.7	39.2	49.2	51.4	64.0	70.4	80.9	72.6	63.3	49.8	38.7	24.9	52.8
	15.2	21.6	28.5	29.2	34.6	44.4	46.6	45.6	41.0	32.2	26.7	11.1	31.4
1969	19.4	34.1	43.0	57.0	66.8	71.3	78.3	82.2	68.4	47.0	41.3	32.0	53.4
	5.3	14.3	20.5	30.8	36.7	43.7	44.8	42.9	40.8	30.5	26.7	22.4	30.0
1970	28.1	35.9	39.8	46.1	66.2	76.6	80.2	82.0	61.7	49.0	37.0	30.1	52.7
	15.9	22.7	21.7	29.2	36.5	46.4	47.4	42.9	34.0	27.7	23.1	17.9	30.3
1971	28.1	35.4	38.5	53.4	67.0	68.1	78.1	85.2	62.6	50.2	37.8	27.4	52.7
	14.6	19.7	22.2	28.5	37.3	41.2	45.1	48.1	36.0	30.5	25.7	12.7	30.1
1972	24.4	33.4	44.9	49.2	63.2	72.5	74.6	82.4	62.5	50.9	38.4	25.3	51.8
	6.8	19.9	27.4	28.2	37.0	44.8	45.7	46.4	36.3	28.3	26.7	12.5	30.0
1973	27.2	35.7	45.6	52.9	66.7	71.2	84.1	85.2	68.8	53.3	34.1	32.4	54.7
	10.1	15.2	25.6	29.2	35.1	43.9	45.4	44.6	39.4	34.1	23.5	23.8	30.8
1974	27.7	37.0	40.8	52.8	57.9	76.8	80.1	77.5	70.7	60.3	39.1	34.3	54.6
	14.0	24.0	23.1	32.3	36.0	44.4	47.4	45.2	36.0	28.5	26.2	23.8	31.7
1975	29.5	28.8	37.4	46.1	60.6	67.3	84.5	71.3	67.1	48.0	36.5	34.0	50.9
	14.0	10.5	20.3	25.9	35.0	41.3	51.0	47.0	37.8	33.6	23.1	22.6	30.1
1976	32.1	36.2	39.8	53.4	68.0	66.5	78.8	73.5	68.8	54.3	39.8	35.0	53.9
	18.9	21.8	19.8	29.8	35.9	42.2	47.2	48.4	39.8	32.0	24.2	22.2	31.9
1977	27.2	39.3	41.2	59.7	61.2	76.5	76.6	74.1	61.9	52.9	35.4	27.1	52.8
	13.6	23.2	25.7	29.1	37.6	43.9	47.9	48.1	38.7	31.1	22.6	13.1	31.2
1978	29.0	34.5	45.5	53.2	57.1	73.7	77.0	71.5	64.3	56.2	33.5	25.2	51.7
	12.8	20.0	24.6	31.9	37.6	43.4	48.7	45.9	42.6	28.8	18.7	9.1	30.3
1979	15.0	31.2	43.7	51.8E	64.2	74.3	81.3	81.6	72.3	57.7	36.1	36.3	53.8
	-7.9	16.6	22.0	30.5E	37.1	42.7	48.1	48.4	39.2	31.2	22.2	24.1	29.5
1980	24.0	34.1	39.1	59.4	67.2	70.0	76.8	71.6	64.6	57.3	40.0	32.2	53.1
	4.9	19.8	21.8	32.0	40.3	41.9	47.0	43.6	40.8	31.3	26.7	19.8	30.6
1981	34.2	35.6	48.5	53.4	63.2	64.5	77.3	82.7	69.1	52.7	42.0	31.2	54.5
	21.6	20.4	24.6	32.5	40.5	42.2	47.4	48.1	38.8	31.3	26.1	18.1	32.6
1982	26.2	31.4	42.5	48.7	62.1	73.5	75.0	78.0	66.2	50.5	33.4	30.4	51.5
	11.0	13.7	26.4	25.5	34.1	45.2	46.8	47.0	40.5	33.6	23.4	17.5	30.4
1983	34.8	38.8	44.0	53.8	66.2	69.9	73.2	80.5	64.7	53.6	39.1	18.7	53.1
	22.6	25.6	28.9	28.7	38.7	44.4	47.8	49.9	36.4	33.0	30.0	4.3	32.5
1984	32.7	38.7	42.9	53.2	58.7	69.6	82.0	80.6	60.9	47.8	35.8	25.8	52.4
	22.3	23.4	29.2	31.6	37.3	43.1	47.2	47.7	37.2	28.9	26.0	12.2	32.2
1985	25.0	28.6	41.4	53.9	68.3	73.1	88.1	74.7	58.0	48.0	23.6	26.6	50.8
	14.5	13.0	20.1	32.0	37.8	42.2	50.1	45.5	38.1	31.4	10.9	16.3	29.3
10-year averages													
1931-40	29.0	30.7	42.4	54.8	66.4	72.6	81.8	80.1	68.4	54.9	38.0	32.4	54.3
	15.2	13.3	23.4	29.5	37.5	44.1	47.8	44.9	40.2	33.0	23.9	20.5	31.1
1941-50	26.8	34.5	41.7	55.8	64.2	68.9	80.5	79.1	66.6	53.7	38.3	31.2	53.4
	11.6	16.8	20.8	30.3	37.6	43.8	47.4	45.9	39.1	32.5	25.7	19.0	30.9
1951-60	28.1	33.4	39.8	51.6	64.0	69.5	79.6	76.5	66.5	52.3	36.6	31.3	52.4
	14.7	17.2	20.1	28.3	36.5	43.0	46.6	45.6	39.0	31.9	23.6	19.8	30.5
1961-70	28.4	36.4	41.6	51.6	63.9	71.7	79.9	78.9	66.2	52.3	38.7	30.2	53.3
	15.4	20.3	21.6	29.4	36.2	43.7	45.9	45.1	38.8	32.1	25.7	18.8	31.1
1971-80	26.4	34.6	41.7	53.2	63.3	71.7	79.2	77.4	66.4	54.1	37.1	30.9	53.0
	10.2	19.1	23.3	29.7	36.9	43.0	47.3	46.6	38.7	30.9	24.0	18.4	30.7

(con.)

Table 29. (Con.)

Polebridge - Observation time 5 p.m., changed to 7 a.m. beginning April 1975

Year		Average daily maximum and minimum temperatures												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annua
		°F												
1948	Max.	32.7	31.5	38.3	51.5	62.8	72.7	75.4	74.8	69.4	58.3	36.1	23.9	52.3
	Min.	7.3	6.0	8.9	26.2	36.3	45.3	39.4	42.4	30.8	22.3	21.8	0.9	24.
1949		16.4	29.8	42.2	59.1	68.0	70.6	77.2	80.7	70.1	49.9	44.8	28.5	53.1
		-13.8	1.7	13.6	26.0	33.8	37.4	42.3	38.1	31.5	25.5	25.6	9.4	22.
1950		13.3	36.2	37.7	49.1	61.2	70.0	79.1	78.7	71.0	51.7	36.8	34.6	51.6
		-11.4	13.0	17.1	24.7	30.3	37.4	40.8	39.1	29.8	31.8	17.5	20.7	24.
1951		26.6	35.8	36.4	55.3	63.7	66.3	80.3	75.2	63.9	46.8	36.1	21.1	50.6
		3.5	6.6	7.9	19.5	32.5	35.0	40.6	38.8	33.0	29.8	18.0	1.4	22.
1952		25.9	36.8	41.0	59.9	64.9	69.5	79.2	78.9	75.3	63.6	38.1	31.2	55.4
		5.5	11.9	13.8	23.7	32.6	38.6	39.4	38.1	31.9	21.6	16.3	17.5	24.
1953		37.0	37.7	44.8	48.5	62.9	67.5	82.5	79.8	72.1	62.7	43.4	33.5	56.0
		23.7	15.2	19.4	24.6	31.4	38.1	38.2	39.9	32.7	24.8	24.5	16.6	27.
1954		26.1	41.7	39.2	44.7	64.2	65.7	79.6	74.3	63.8	52.5	44.7	32.0	52.4
		5.1	18.0	7.9	22.5	31.1	37.7	39.9	40.9	35.5	24.6	27.0	17.2	25.
1955		29.0	30.1	33.7	46.5	58.3	73.3	75.7	81.9	68.0	55.0	28.5	27.5	50.6
		13.6	7.5	7.7	25.1	30.8	36.5	43.9	33.7	30.8	30.6	10.8	5.7	23.
1956		30.1	30.9	40.2	53.0	65.2	71.3	80.8	78.6	69.9	50.6	36.1	33.9	53.4
		10.7	5.2	16.2	23.0	33.0	38.1	42.5	38.8	32.8	28.5	17.1	12.1	24.
1957		16.2	32.8	42.2	51.5	68.7	70.9	79.0	77.0	72.9	47.4	38.8	35.5	52.7
		-8.9	8.5	15.6	25.7	34.2	40.8	40.1	36.3	30.5	27.1	17.2	17.5	23.
1958		33.8	38.0	41.8	51.4	75.0	72.7	79.1	85.6	68.5	56.5	35.3	32.6	55.9
		15.6	18.1	14.0	27.2	34.4	41.8	42.6	41.5	34.4	24.6	17.3	15.6	27.
1959		29.7	30.9	43.4	53.4	59.3	72.2	82.3	75.4	64.5	50.2	33.0	31.8	52.2
		9.5	5.6	21.1	25.5	29.5	39.2	38.8	37.9	37.7	29.8	10.1	10.2	24.
1960		26.3	33.5	42.7	51.5	59.4	72.8	89.2	76.9	73.7	56.5	37.4	28.8	54.1
		2.2	7.5	15.5	26.5	32.2	36.5	39.8	38.8	29.4	25.9	21.5	11.0	23.
1961		33.3	39.5	44.6	49.4	65.3	81.0	82.8	87.1	62.9	51.3	35.0	27.9	55.0
		10.1	24.1	20.8	26.8	34.1	38.3	42.2	41.4	29.8	25.0	12.5	10.3	26.
1962		26.1	33.0	40.5	58.6	60.5	73.4	78.8	76.1	70.9	55.3	40.2	34.1	54.0
		.9	10.0	14.3	26.6	33.3	35.6	39.4	38.3	29.3	31.2	27.0	22.6	25.
1963		17.7	42.8	44.9	54.0	64.7	70.1	78.6	80.4	75.0	59.6	39.3	28.4	54.6
		-5.4	17.5	20.8	27.4	29.8	41.3	39.2	38.2	36.0	30.1	22.9	10.7	25.
1964		31.9	36.9	37.0	50.2	61.5	69.2	80.5	72.8	62.5	55.2	38.8	25.0	51.8
		15.5	12.3	14.1	26.4	29.8	37.5	40.9	37.9	32.9	27.1	22.3	7.6	25.
1965		32.9	34.9	38.5	54 E	61.2	70.0	80.7	77.4	54.3	59.8	39.6	32.1	53.0
		18.6	12.8	4.3	27 E	31.8	39.7	40.7	43.0	31.5	28.1	22.0	16.9	26.
1966		28.4	37.1	44.3	52.1	68.4	67.3	80.6	77.5	76.5	54.4	37.9	33.0	54.8
		12.0	11.5	16.1	25.6	33.1	37.6	40.7	37.9	35.0	27.2	20.0	18.6	26.
1967		33.7	38.2	37.7	48.8	62.5	72.6	87.1	91.2	84.5	56.1	39 E	29.7	56.8
		16.1	15.9	15.9	23.2	30.8	36.8	40.1	37.8	36.3	29.4	20 E	12.5	26.
1968		30 E	41 E	50 E	52 E	63.4	71.4	82.6	75.2	67.5	52.5	38.8	23.3	54.0
		10 E	16 E	24 E	26 E	31.8	38.4	40.3	40.8	37.4	28.5	22.7	7.0	26.
1969		20.2	37.9	47.3	57.7	67.6	71.6	79.5	86.5	73.4	50.2	41.4	31.7	55.4
		0.4	9.6	16.4	29.0	32.2	40.7	38.1	34.1	35.1	25.9	21.8	17.8	25.
1970		28.3	39.4	42.0	47.2	67.1	77.4	83.3	86.2	63.9	53.4	38.4	29.2	54.7
		11.2	15.1	16.5	25.8	31.8	42.6	42.9	36.5	31.6	24.0	17.7	8.8	25.
1971		27.8	36.2	39.2	52.9	66.0	66.5	77.2	83.5	62.6	50.6	38.0	25.7	52.2
		9.6	15.5	16.8	25.3	33.1	38.3	39.3	42.0	29.8	22.8	21.6	5.9	25.
1972		23.2	35.1	46.6	50.2	62.5	71.6	74.8	84.8	62.5	51.1	39.0	25.0	52.2
		0.4	15.2	23.7	24.2	32.0	41.2	40.7	42.0	33.0	23.7	21.9	6.1	25.
1973		28.4	38.2	45.9	52.7	65.5	69.7	83.1	83.3	68.1	53.9	32.4	32.1	54.4
		6.2	9.1	22.6	25.9	30.8	39.6	40.8	39.0	34.5	27.9	19.3	18.4	26.
1974		25.2	37.5	41.0	54.0	56.9	76.7	79.0E	75.8	71.4	61.4E	39.4	32.9	54.3
		9.9	18.9	18.4	28.8	33.5	40.6	42.7E	40.0	30.3	22.3E	21.6	17.1	27.
1975		29.0	28.9	36.5	44.8	59.1	67.2	84.0	70.5	69.1	49.5	38.1	32.4	50.8
		7.2	5.3	14.7	18.5	30.3	37.9	44.9	40.8	31.1	28.7	17.4	14.6	24.
1976		32.5	36.7	37.9	52.8	66.0	64.2	75.7	72.7	71.4	55.1	41.2	35.1	53.4
		10.8	15.6	12.5	26.0	32.1	36.5	42.7	44.5	32.8	21.3	16.7	13.9	25.
1977		26.3	41.2	41.3	59.3	59.6	75.3	74.9	73.3	62.3	55.3	36.1	27.0	52.7
		6.0	15.2	20.7	23.3	32.0	38.1	42.0	40.8	33.9	22.0	17.1	5.1	24.
1978		27.4	35.3	45.8	52.7	56.9	72.6	76.9	72.9	66.8	59.6	35.1	27.1	52.4
		6.4	13.4	17.2	26.6	32.6	37.5	42.5	38.1	35.6	21.8	11.8	-1.8	23.
1979		15.7	33.1	46.1	51.8	63.0	73.4	80.5	82.7	75.0	59.2	36.9	38.6	54.7
		-18.2	6.9	16.3	25.6	31.0	35.5	38.3	37.9	32.0E	22.7	13.4	19.4	21.
1980		24.6E	35.5	39.3	58.0	66.6	68.6	77.1	70.8	66.4	59.6	42.3	33.1	53.5
		-3.0E	16.3	19.5	25.9	34.8	38.1	40.4	37.5	32.7	21.1	17.6	11.9	24.

(con

able 29. (Con.)

Year	Average daily maximum and minimum temperatures												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	°F												
981	32.9	36.1	48.7	53.4	62.6	63.2	75.1	83.5	70.1	52.9	43.9	30.6	54.4
	11.5	13.9	17.8	28.0	36.0	38.3	41.2	38.8	29.3	22.9	18.8	10.1	25.6
982	27.5	31.9	42.4	47.0	61.5	72.7	74.7	77.3	66.1	55.0	35.1	29.8	51.8
	5.4	4.6	18.0	19.6	28.6	39.8	40.8	38.1	30.5	25.2	17.4	7.3	22.9
983	34.9	39.9	43.9	54.4	64.4	68.2	72.5	81.8	64.4	56.9	40.4	18.2	53.3
	14.4	20.0	23.5	23.2	29.7	39.2	40.6	41.1	28.6	22.5	25.1	-8.5	25.0
984	32.4	40.6	45.0	53.2	58.0	68.5	80.9	80.9	60.5	50.0	37.1	24.8	52.7
	13.0	16.2	23.5	25.8	31.2	37.3	39.1	39.2	30.0	21.5	18.0	1.8	24.7
985	24.7	29.9	42.7	55.6	68.0	70.7	87.5	74.8	58.1	49.9	23.2	27.3	51.0
	6.1	0.0	10.3	25.4	31.5	35.5	39.1	37.4	30.8	24.2	0.9	6.5	20.6
10-year averages													
951-60	28.1	34.8	40.5	51.6	64.2	70.2	80.8	78.4	69.3	54.2	37.1	30.8	53.3
	8.1	10.4	13.9	24.3	32.2	38.2	40.6	38.5	32.9	26.7	18.0	12.5	24.7
961-70	28.3	38.1	42.7	52.4	64.2	72.4	81.5	81.0	69.1	54.8	38.8	29.4	54.4
	8.9	14.5	16.3	26.4	31.9	38.9	40.5	38.6	33.5	27.7	20.9	13.3	26.0
971-80	26.0	35.8	42.0	52.9	62.2	70.6	78.3	77.0	67.6	55.5	37.9	30.9	53.1
	3.5	13.1	18.2	25.0	32.2	38.3	41.4	40.3	32.6	23.4	17.8	11.1	24.7

(con.)

Table 29. (Con.)

Summit - Observation time, mostly about 5 p.m.

Year		Average daily maximum and minimum temperatures												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
		°F												
1935	Max.	M	35.1	30.7	38.0	54.5	61.7	74.3	70.5	64.9	48.6	31.4	29.7	46.7E
	Min.	M	16.0	11.5	11.7	25.9	36.3	39.3	37.3	33.0	22.3	15.4	17.8	22.6
1936		25.6	8.6	30.1	45.6	63.9	66.7	80.0	74.8	60.8	52.5	37.9	27.1	47.8
		10.8	-18.9	13.3	22.8	33.1	39.3	41.7	39.2	35.6	31.0	18.6	10.7	23.1
1937		6.8	23.9	33.1	42.6	57.3	62.4	72.3	68.2	61.5	51.8	34.7	27.5	45.2
		-13.4	5.2	12.0	23.2	30.6	36.4	41.3	40.1	32.2	32.6	19.6	12.2	22.7
1938		27.1	24.5	34.2	44.8	52.5	64.7	73.3	70.4	71.9	52.1	29.3	27.4	47.7
		13.8	2.8	17.9	25.4	31.2	38.3	43.8	37.4	35.4	29.9	16.9	13.2	25.5
1939		29.2	21.0	36.5	48.1	59.3	57.1	74.5	75.3	63.3	48.8	45.9	34.7	49.5
		17.6	3.8	17.1	24.4	33.1	35.2	40.4	35.4	36.1	31.2	27.6	21.5	27.0
1940		26.4	28.4	39.1	41.9	61.1	67.0	75.4	76.5	65.1	51.0	27.1	30.9	49.2
		5.3	12.0	23.1	24.2	31.5	37.4	40.1	35.8	38.9	33.6	9.6	15.0	25.5
1941		31.2	32.6	42.1	52.1	55.9	62.7	73.4	70.5	51.8	47.8	40.2	27.6	49.0
		11.7	6.9	15.3	22.8	32.4	38.3	41.8	38.5	32.5	26.6	23.7	15.4	25.5
1942		26.3	24.5	35.8	50.0	51.8	56.2	71.1	69.9	61.7	51.7	31.2	30.5	46.7
		10.5	7.0	15.8	25.3	30.8	37.8	39.9	38.6	34.9	30.4	16.5	17.5	25.4
1943		16.3	32.6	29.0	48.6	49.7	55.5	72.4	71.5	65.7	53.4	39.9	29.1	47.0
		-2.3	15.2	6.5	27.7	28.9	34.6	41.1	39.0	32.9	28.0	22.5	13.2	23.9
1944		30.2	26.1	29.9	49.1	59.1	60.3	70.9	68.2	62.4	59.9	32.1	25.4	47.8
		15.5	6.9	8.9	23.5	31.6	37.8	38.4	36.3	32.7	30.0	20.6	10.0	24.4
1945		27.9	29.8	33.9	36.8	M	M	74.2	74.3	55.7	53.5	32.3	28.0	M
		14.3	10.1	17.5	19.6	M	M	39.9	37.6	32.5	32.4	19.5	12.9	M
1946		29.2	29.9	41.1	50.3	58.1	62.5	76.1	73.2	59.8	40.1	28.8	29.5	48.2
		19.7	20.1	20.6	26.5	29.7	35.7	40.9	37.5	34.0	24.5	14.2	14.4	26.5
1947		24.2	30.7	35.9	47.1	59.6	59.2	78.8	70.7	58.7	48.8	31.4	30.5	48.0
		7.7	7.9	15.0	27.2	32.5	37.9	39.0	37.0	35.8	32.5	14.7	17.3	25.4
1948		28.1	23.9	29.1	44.3	54.0	64.8	69.1	70.5	64.4	54.8	31.0	20.6	46.2
		12.4	.8	7.8	20.8	31.4	41.8	38.2	40.3	32.7	25.5	20.3	5.1	23.1
1949		12.9	23.9	35.1	52.4	61.8	64.1	71.7	76.7	61.0	41.7	44.7	23.5	47.5
		-10.5	2.0	10.8	28.1	30.3	36.6	39.5	36.5	31.5	26.0	30.0	1.9	21.9
1950		4.0	29.8	27.8	39.6	49.7	58.8	70.6	70.4	62.8	47.3	32.6	32.5	43.8
		-16.0	17.0	12.3	20.3	29.4	36.2	39.4	38.2	31.6	30.4	15.0	19.7	22.8
1951		21.5	28.9	24.3	45.7	55.5	57.1	73.4	68.8	56.3	40.8	32.2	19.2	43.6
		5.0	5.9	4.9	18.2	29.7	31.5	39.5	37.5	30.7	26.4	19.1	3.4	21.0
1952		21.3	30.1	32.6	52.9	57.5	61.2	69.6	70.7	66.3	58.3	32.6	29.6	48.6
		6.8	14.9	11.2	22.8	32.4	37.4	39.6	38.6	36.1	29.1	17.7	18.9	25.5
1953		32.3	30.0	37.9	38.1	52.9	60.5	74.8	73.6	65.8	57.5E	40.0E	29.5E	49.4
		19.6	17.3	19.2	19.5	29.3	36.2	38.7	38.5	34.3	30.0E	25.0E	17.5E	27.1
1954		19.6	35.7	29.1	35.9	51.9	57.6	72.8	68.5	59.0	47.1	42.7	31.5	46.0
		-.7	23.4	7.4	21.9	29.7	37.8	40.0	37.6	32.9	25.2	28.9	16.7	25.1
1955		25.6	23.6	25.4	43.2	50.9	65.2	70.9	75.7	58.7	50.0	22.8	24.9	44.7
		13.9	8.0	5.8	24.9	31.7	37.6	45.0	38.8	32.3	30.7	2.9	6.9	23.2
1956		24.8	24.2	34.2	43.7	55.0E	63.9	72.8	69.5	61.9	45.7	33.4E	28.9E	46.5
		7.9	6.2	16.7	22.0	32.8E	38.3	41.7	38.8	33.8	28.2	19.5E	14.6E	25.0
1957		13.7	26.1	36.5	44.4	60.1	62.6	73.5	70.2	65.4	43.4	33.1	32.5	46.8
		-7.2	9.5	15.2	23.7	31.9	38.1	41.2	40.1	34.0	24.7	19.2	21.1	24.3
1958		32.4	31.5	33.8	42.5	66.6	60.7	67.4	74.7	57.6	51.5	28.2	27.9	47.9
		20.3	14.1	12.5	25.0	33.6	37.6	39.4	44.0	35.1	31.2	17.0	16.3	27.2
1959		25.5	24.1	35.3	45.5	52.0	68.1	76.6	67.0	55.4	44.9	29.4	31.5	46.2
		6.7	4.3	21.3	22.8	28.7	38.3	38.4	38.5	33.4	26.0	12.3	18.0	24.1
1960		22.9	25.1	34.6	43.0	55.2	65.9	82.2	68.3	66.9	49.1	31.3	30.0	47.9
		6.9	9.3	14.4	23.2	29.6	36.8	41.5	39.5	33.4	30.6	17.8	14.3	24.8
1961		31.1	33.6	37.1	42.5	57.9	74.5	75.4	82.8	52.9	45.8	30.9	21.2	48.8
		15.4	20.8	18.6	21.9	32.0	39.8	40.9	41.6	28.9	27.3	13.8	9.3	25.9
1962		21.3	23.6	33.6	52.4	53.6	66.0	69.7	67.2	59.2	46.3	33.9	28.7	46.3
		4.5	6.3	10.5	26.3	32.0	38.2	35.5	39.4	32.1	28.6	23.1	13.2	24.1
1963		14.2	37.6	40.7	47.2	57.3	63.4	71.4	74.9	69.2	53.9	36.3	26.5	49.4
		-5.6	20.8	19.9	22.7	29.0	39.0	40.0	38.7	37.6	31.7	21.8	13.4	25.8
1964		26.3	30.6	29.1	42.3	51.8	61.6	73.7	65.2	52.4	51.1	34.2	20.5	44.9
		15.6	17.6	12.7	23.2	29.7	38.2	42.5	38.5	30.9	30.1	20.2	3.0	25.2
1965		26.7	26.8	26.9	45.0	51.2	61.3	71.7	68.5	45.4	52.9	32.9	27.9	44.8
		16.1	10.7	.1	23.4	29.9	35.7	39.3	40.0	27.5	33.2	18.8	12.1	23.9
1966		19.7	28.4	35.5	42.6	56.3	58.6	71.6	70.5	67.3	47.8	35.2E	28.0E	46.8
		1.3	12.0	16.0	21.8	29.5	33.7	39.7	37.5	38.7	31.8	18.0E	15.0E	24.6
1967[1]		27.7	30.9	28.6	38.1	52.2	61.4	74.2	78.1	71.2	47.0	34.7	23.8	47.3
		13.0	17.0	7.8	18.4	29.0	35.1	43.8	38.0	37.7	30.0	20.3	9.7	25.0

(con.

Table 29. (Con.)

Year	Average daily maximum and minimum temperatures												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
	°F												
1968	28.1	37.2	43.2	42.3	55.5	63.5	73.7E	66.0E	60.5	46.9	34.8	19.1	47.6
	9.7	17.6	23.7	22.5	28.1	38.6	41.0E	41.0E	37.2	29.3	21.7	1.4	26.0
1969	12.0	30.8	37.5	51.9	60.2	62.7	72.0	77.2	63.3	41.5	37.6	29.6	48.0
	-8.1	7.6	12.7	26.6	31.0	36.6	39.3	40.8	33.5	22.6	21.6	17.6	23.5
1970	23.4	34.3	32.1	38.2	55.9	70.0	75.8	76.5	53.2	45.7	34.6	24.2	47.0
	7.3	15.8	12.9	18.8	29.5	39.8	43.9	37.6	31.6	23.2	14.7	8.5	23.6
1971	20.5	31.1	30.4	44.3	57.8	60.4	69.8	80.0	56.7	45.6	34.9	22.3	46.2
	4.2	13.1	12.0	21.4	28.1	35.8	35.9	41.6	32.6	27.2	22.9	4.9	23.3
1972	18.5	30.6	41.5	43.1	55.0	68.7	70.3	75.9	53.1	48.8	35.5	21.0	46.8
	-.4	12.6	21.7	21.3	31.0	39.2	41.5	43.1	30.9	26.0	23.4	8.3	24.9
1973[1]	25.6	36.8	41.1	43.9	58.1	63.2	74.4	72.8	59.0	43.8	21.8	26.0	47.2
	7.4	13.4	20.6	23.0	30.1	38.5	35.7	39.8	33.1	25.3	10.0	15.6	24.4
1974	20.0E	29.8	33.6	46.7	49.6	71.7	71.4	66.1	59.7	52.4	34.2	31.1	47.2
	7.0E	19.3	14.4	27.5	31.6	40.2	40.6	39.1	32.8	29.6	21.2	19.1	26.9
1975	22.9	20.9	24.5	34.9	49.2	59.0	73.3	62.3	63.8	44.5	31.7	27.7	42.9
	6.3	4.8	9.1	19.3	30.2	34.9	46.7	38.4	36.1	31.8	18.9	15.0	24.3
1976	25.7	27.5	30.1	46.6	59.5	59.2	71.0	68.2	65.5	50.9	39.5	30.6	47.9
	13.5	14.4	11.6	24.8	32.4	37.0	44.8	46.5	39.9	33.5	22.5	19.4	28.4
1977	22.8	36.5	33.5	50.1	54.1	69.0	69.6	64.0	58.3	48.1	29.2	20.0E	46.3
	9.2	23.1	19.1	26.4	31.3	39.4	45.5	39.7	35.1	29.0E	16.2	7.0E	26.8
1978	18.5	27.8	40.5	41.6	49.4	65.5	70.3	66.5	58.6	52.2	29.0	19.7	45.0
	3.8	11.9	26.2	26.0	32.4	38.6	46.2	43.8	41.8	31.5	15.1	6.1	27.0
1979	12.1	23.6	37.8	43.0	(Station closed)								
	-4.9	5.1	20.3	26.3									
10-year averages													
1941-50	23.0	28.4	34.0	47.0	55.5	60.5	72.8	71.6	60.4	49.9	34.4	27.7	47.1
	6.3	9.4	13.1	24.2	30.8	37.4	39.8	38.0	33.1	28.6	19.7	12.7	24.4
1951-60	24.0	27.9	32.4	43.5	55.8	62.3	73.4	70.7	61.3	48.8	32.6	28.6	46.8
	7.9	11.3	12.9	22.4	30.9	37.0	40.5	39.2	33.6	28.2	17.9	14.8	24.7
1961-70	23.1	31.4	34.4	44.3	55.2	64.3	72.9	72.7	59.5	47.9	34.5	25.0	47.1
	6.9	14.6	13.5	22.6	30.0	37.5	40.5	39.3	33.6	28.8	19.4	10.3	24.8
1971-79	20.7	29.4	34.8	43.8	54.1	64.6	71.3	69.5	59.3	48.3	32.0	24.8	46.1
(8 or 9 yr.)	5.1	13.1	17.2	24.0	30.9	38.0	42.1	41.5	35.3	29.3	18.8	11.9	25.6

[1]Station site changed in 1967 and again in 1973.

Table 30.--Daily maximum and minimum temperature statistics (°F) for West Glacier, Polebridge, and Summit; based on years 1949-78, except as noted, and on 24-hour period ending about 5 p.m., m.s.t. Also, July-August data for Desert Mountain Lookout; based on 1951-70 and 24 hours ending at 4 p.m. Letter M following year of highest or lowest average denotes average computed with incomplete data; based on at least 6 daily values per 10-day period

MAXIMUM DAILY TEMPERATURE

STATION NUMBER 248809 WEST GLACIER

MEAN, STANDARD DEVIATION, AND EXTREME VALUES 1949-1978

	10-DAY AND MONTHLY PERIOD MEANS						10-DAY AND MONTHLY EXTREMES								
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR		HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	26.6	6.4	27.5	37.6 54	12.1 74		47 54	37.1	5.8	37.0	-4 59	13.6	9.3	12.5	JAN 1
JAN 11	27.8	8.3	29.0	39.4 53	6.8 50		48 74	37.2	6.7	39.5	-12 50	14.8	12.4	13.5	JAN 11
JAN 21	27.5	9.0	30.0	39.1 71	8.2 69		49 62	37.8	7.6	39.0	-6 72	14.7	12.7	18.0	JAN 21
FEB 1	32.9	6.1	33.5	41.6 52	16.1 75		52 63	41.5	5.3	40.5	0 50	22.7	10.0	22.5	FEB 1
FEB 11	35.0	4.1	35.0	45.9 77	25.0 56		50 77	42.5	3.4	42.0	2 56	26.8	9.0	30.0	FEB 11
FEB 21	36.5	6.3	36.5	45.6 73	17.6 62		58 50	43.2	6.3	44.5	7 57	29.2	8.4	31.0	FEB 21
MAR 1	36.5	5.7	36.0	51.1 68	18.6 51		61 68	45.2	5.7	45.0	0 51	25.6	9.5	26.5	MAR 1
MAR 11	41.2	3.7	41.5	48.4 72	34.1 67		59 68	49.3	4.9	48.5	14 65	32.4	7.0	34.0	MAR 11
MAR 21	44.4	5.7	44.5	54.7 78	31.9 55		63 66	53.3	5.7	54.0	10 55	34.7	8.7	37.0	MAR 21
APR 1	49.9	5.0	49.0	58.5 60	39.2 75		72 77	58.3	6.4	58.0	20 54	40.9	5.3	41.0	APR 1
APR 11	51.6	5.4	50.5	65.6 62	42.8 55		75 62	61.7	6.8	61.0	32 51	41.5	4.9	40.5	APR 11
APR 21	54.5	6.2	54.5	71.5 77	42.6 54		79 77	65.3	7.5	66.0	33 54	44.1	6.0	42.5	APR 21
MAY 1	60.1	6.3	59.0	76.2 66	51.3 64		82 66	69.9	6.3	70.5	35 51	48.0	7.4	47.0	MAY 1
MAY 11	64.2	5.5	64.0	75.1 73	50.3 74		83 73	74.9	5.6	76.5	43 59	52.2	5.4	52.0	MAY 11
MAY 21	66.3	5.3	66.0	79.3 58	56.7 78		86 66	76.2	5.6	76.0	45 73	55.8	6.1	55.5	MAY 21
JUN 1	69.5	5.4	68.0	80.9 70	60.6 54		89 70	78.4	5.9	78.0	49 74	58.3	6.3	58.5	JUN 1
JUN 11	71.1	5.5	70.0	86.5 74	62.3 54		90 74	80.7	5.3	80.5	49 54	60.4	6.6	60.5	JUN 11
JUN 21	71.9	5.4	70.5	81.0 61	61.5 69		90 70	82.2	5.6	82.5	45 60	58.9	7.2	57.0	JUN 21
JUL 1	76.9	5.6	76.5	87.6 75	61.9 55		94 73	85.4	4.5	86.0	46 55	66.9	7.2	68.0	JUL 1
JUL 11	80.2	4.7	80.0	88.4 60	70.1 72		96 75	87.7	4.4	88.0	57 63	70.1	6.8	70.0	JUL 11
JUL 21	81.3	3.5	81.0	87.4 74	74.4 49		93 75	88.4	2.3	88.5	59 52	70.9	6.9	72.5	JUL 21
AUG 1	80.9	4.4	82.0	89.5 71	72.5 62		96 61	88.0	3.7	88.0	60 56	71.0	5.8	71.5	AUG 1
AUG 11	78.9	6.6	79.5	92.9 67	64.6 68		95 73	85.5	4.5	85.0	56 68	70.6	8.7	72.5	AUG 11
AUG 21	73.8	6.9	73.0	85.2 67	60.9 60		99 69	83.4	6.4	83.5	50 60	62.7	7.7	62.0	AUG 21
SEP 1	71.6	6.2	69.5	87.5 67	57.4 64		94 67	80.1	6.5	79.5	49 65	59.9	6.8	60.0	SEP 1
SEP 11	65.5	6.2	65.0	75.1 66	46.1 65		87 73	75.2	7.4	76.0	38 65	54.1	6.8	55.0	SEP 11
SEP 21	61.9	8.1	60.5	79.2 67	49.3 61		89 63	70.7	9.2	70.5	37 72	52.0	9.2	51.5	SEP 21
OCT 1	57.1	5.4	56.0	67.4 52	48.0 49		76 57	66.9	5.7	68.0	34 57	47.5	6.4	46.0	OCT 1
OCT 11	53.2	5.4	52.0	62.7 74	42.3 51		69 76	60.6	6.1	61.5	30 51	44.9	6.1	44.5	OCT 11
OCT 21	47.5	5.5	48.0	57.5 74	37.5 75		65 55	55.9	6.1	57.0	24 71	39.7	7.4	41.5	OCT 21
NOV 1	41.8	4.4	41.5	49.5 65	28.7 73		60 75	50.6	6.1	51.0	18 73	33.6	6.7	35.5	NOV 1
NOV 11	36.4	6.4	37.0	43.5 54	15.4 55		57 56	43.9	5.9	42.5	2 55	28.6	9.0	31.0	NOV 11
NOV 21	34.6	4.1	34.5	43.3 49	26.2 75		53 62	43.5	5.5	42.5	10 77	25.5	7.2	26.5	NOV 21
DEC 1	31.6	5.6	32.5	40.9 75	10.9 72		52 65	41.0	5.6	40.0	-3 72	22.6	9.7	26.0	DEC 1
DEC 11	30.1	6.6	30.5	38.3 62	16.3 64		46 59	38.7	3.7	39.0	-8 64	21.6	11.4	25.5	DEC 11
DEC 21	30.3	6.3	31.0	37.6 50	10.9 68		51 49	39.8	5.7	40.0	-9 68	19.9	9.6	21.5	DEC 21
MONTH															MONTH
JAN	27.3	5.4	28.0	37.0 53	13.9 50		49 62	42.7	4.0	43.0	-12 50	6.5	9.9	5.0	JAN
FEB	34.7	3.2	35.0	40.1 63	28.7 49		58 50	46.4	4.1	46.5	0 50	18.7	8.9	18.0	FEB
MAR	40.8	3.5	40.5	49.2 68	33.0 55		63 66	54.1	5.0	54.5	0 51	23.4	9.7	24.5	MAR
APR	52.0	4.0	51.5	60.0 52	44.8 54		79 77	66.9	6.5	66.5	20 54	38.1	4.4	39.0	APR
MAY	63.6	3.8	63.0	74.6 58	57.1 78		86 66	78.6	4.1	79.0	35 51	45.8	4.9	45.0	MAY
JUN	70.8	3.5	71.0	79.7 61	64.7 54		90 74	85.3	3.5	86.0	45 60	53.9	4.3	53.5	JUN
JUL	79.5	2.7	78.5	84.9 67	74.2 55		96 75	90.2	2.5	89.5	46 55	63.3	5.8	62.5	JUL
AUG	77.8	4.9	77.0	87.4 67	70.2 64		99 69	89.3	3.9	89.0	50 60	61.6	6.8	61.5	AUG
SEP	71.3	4.5	71.0	80.4 67	63.9 65		94 67	81.3	5.8	80.0	37 72	48.5	6.4	48.5	SEP
OCT	56.3	5.2	57.0	63.8 74	47.8 55		81 74	69.8	5.8	70.0	27 71	34.7	7.3	40.5	OCT

MINIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 248809 WEST GLACIER

1949-1978

10-DAY AND MONTHLY PERIOD MEANS

10-DAY AND MONTHLY EXTREMES

PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	12.3	9.1	13.5	29.1 54	-6.5 74	34 63	26.4	6.7	28.5	-28 49	-6.5	13.1	-1.0	JAN 1
JAN 11	14.5	11.3	18.5	29.3 53	-10.4 50	37 74	27.1	7.3	29.0	-33 49	-2.9	16.5	-0.5	JAN 11
JAN 21	12.8	11.9	14.5	31.4 53	-10.0 57	36 71	27.1	8.9	30.0	-35 50	-6.7	16.7	-1.0	JAN 21
FEB 1	16.9	8.0	17.5	28.9 61	-4.3 75	34 68	29.1	5.3	31.0	-32 50	-0.5	14.3	2.0	FEB 1
FEB 11	19.9	6.7	21.0	28.5 76	5.2 56	36 49	30.7	2.7	31.0	-30 56	4.6	11.8	7.0	FEB 11
FEB 21	19.0	8.2	19.5	29.0 54	-5.1 62	36 72	29.7	4.7	31.0	-23 62	6.6	12.4	8.5	FEB 21
MAR 1	17.9	5.7	18.0	29.1 77	0.2 51	36 68	30.7	3.6	31.0	-30 60	2.8	11.1	4.0	MAR 1
MAR 11	21.6	5.5	22.0	32.0 72	9.8 65	37 76	31.8	2.8	32.0	-20 56	7.5	12.5	9.0	MAR 11
MAR 21	24.7	5.9	26.0	32.1 78	8.8 55	37 68	32.9	2.5	33.0	-21 55	13.6	12.3	18.0	MAR 21
APR 1	27.4	2.6	27.0	31.4 74	19.4 75	39 63	34.7	2.4	35.0	3 54	18.7	5.4	20.5	APR 1
APR 11	28.6	2.4	28.0	33.1 58	21.1 51	42 62	36.7	2.5	36.0	5 51	20.9	4.3	21.0	APR 11
APR 21	31.0	2.5	30.0	36.8 53	25.8 54	44 74	38.2	3.4	38.0	9 51	23.5	4.2	24.0	APR 21
MAY 1	34.1	2.3	34.0	40.2 57	30.5 65	50 57	41.2	3.5	40.5	13 54	26.7	3.4	27.0	MAY 1
MAY 11	36.0	2.0	35.0	40.5 49	33.1 66	57 70	43.8	3.7	43.0	25 59	29.6	2.5	29.5	MAY 11
MAY 21	38.7	2.8	38.0	46.7 58	33.0 75	55 50	47.7	3.6	48.0	26 67	30.2	2.8	30.0	MAY 21
JUN 1	41.9	2.9	41.0	46.9 57	36.7 50	57 52	50.1	3.3	49.0	24 59	33.9	3.7	34.0	JUN 1
JUN 11	43.4	2.4	43.0	49.1 58	39.8 69	59 66	50.9	3.6	49.5	27 69	35.3	4.0	35.0	JUN 11
JUN 21	44.2	2.4	44.0	49.2 70	40.2 64	60 68	52.7	3.7	52.0	32 75	37.1	3.0	37.0	JUN 21
JUL 1	45.8	2.9	45.0	53.6 75	40.6 59	61 75	54.5	3.8	54.0	32 73	38.0	3.6	38.0	JUL 1
JUL 11	47.2	2.4	46.0	51.7 75	42.3 65	64 67	56.5	4.1	57.0	32 65	39.3	3.4	39.5	JUL 11
JUL 21	46.8	2.6	46.0	51.2 77	42.3 54	62 60	55.1	3.8	56.0	34 73	39.8	2.8	40.0	JUL 21
AUG 1	47.2	2.7	47.0	53.9 76	42.3 69	62 68	55.0	3.6	54.0	36 75	40.4	3.4	39.5	AUG 1
AUG 11	45.6	2.5	45.0	51.1 75	41.0 70	62 58	53.3	3.8	52.5	32 59	38.3	3.2	39.0	AUG 11
AUG 21	44.4	2.7	43.5	51.1 58	39.2 55	62 58	53.1	3.9	52.5	32 65	36.7	3.3	37.0	AUG 21
SEP 1	41.0	3.3	40.0	48.5 78	33.2 62	67 67	51.0	5.4	50.0	27 62	33.4	3.8	33.0	SEP 1
SEP 11	38.1	4.1	38.0	45.2 68	29.0 70	57 76	48.5	4.5	48.5	19 70	30.2	4.6	30.0	SEP 11
SEP 21	36.7	3.3	36.5	42.2 69	30.2 70	63 67	45.9	5.4	45.0	20 61	29.4	3.2	29.0	SEP 21
OCT 1	33.7	2.7	33.0	40.2 51	29.2 74	50 76	43.1	4.1	44.0	18 50	26.3	3.2	26.0	OCT 1
OCT 11	31.8	3.5	32.0	38.7 56	24.6 69	49 50	40.2	3.7	41.0	18 76	24.7	3.6	25.0	OCT 11
OCT 21	30.0	3.1	29.5	36.0 73	24.0 71	48 62	39.6	4.4	41.0	3 71	21.7	5.3	22.0	OCT 21
NOV 1	26.5	4.5	26.0	34.5 62	17.9 73	44 75	34.7	4.5	34.0	4 71	17.3	6.7	18.0	NOV 1
NOV 11	24.4	8.2	26.5	34.7 54	0.5 55	40 67	33.4	4.2	33.0	-29 59	13.0	12.4	17.5	NOV 11
NOV 21	22.7	4.3	22.0	30.0 49	13.4 70	41 62	32.3	3.4	32.0	-10 77	9.6	8.8	11.5	NOV 21
DEC 1	19.8	7.7	21.0	28.8 64	-7.7 72	39 75	30.9	3.3	31.5	-25 72	6.1	12.2	7.5	DEC 1
DEC 11	18.8	8.6	19.5	31.6 62	0.8 64	36 62	29.7	4.1	32.0	-32 64	5.4	13.4	7.5	DEC 11
DEC 21	17.9	8.1	19.0	29.1 50	-3.7 68	35 50	29.3	4.9	31.0	-36 68	2.4	13.2	4.5	DEC 21
MONTH														MONTH
JAN	13.2	7.8	14.0	27.1 53	-5.8 49	37 74	32.0	3.2	32.0	-35 50	-14.7	13.2	-1.0	JAN
FEB	18.6	4.6	19.0	27.7 61	9.3 49	36 72	32.5	1.7	32.0	-32 50	-6.9	13.2	-1.0	FEB
MAR	21.5	4.0	21.0	28.5 68	12.9 65	37 76	34.2	1.8	34.5	-30 60	-1.4	12.3	-0.5	MAR
APR	29.0	1.7	29.0	32.3 74	24.0 51	44 74	39.4	2.7	40.0	3 54	17.2	5.3	19.0	APR
MAY	36.3	1.6	36.0	40.3 58	33.6 55	57 70	48.4	3.6	48.0	13 54	26.2	3.0	26.5	MAY
JUN	43.2	1.6	43.0	46.5 58	39.8 51	60 68	54.5	3.3	55.0	24 59	32.2	3.1	32.0	JUN
JUL	46.6	1.6	46.0	51.0 75	43.9 65	64 67	58.5	2.5	59.0	32 73	36.4	2.5	36.0	JUL
AUG	45.7	1.8	45.0	49.4 58	42.1 55	62 68	56.9	3.0	57.0	32 65	35.6	2.4	35.5	AUG
SEP	38.6	2.5	38.0	43.3 67	34.0 70	67 67	52.5	4.6	52.0	19 70	27.6	3.2	28.0	SEP
OCT	31.7	2.1	31.0	35.1 63	27.7 70	50 76	44.7	2.9	44.5	3 71	20.7	4.9	20.0	OCT
NOV	24.5	3.7	24.0	31.4 54	15.6 55	44 75	36.6	3.4	36.0	-29 59	5.3	10.8	7.0	NOV
DEC	18.8	4.9	18.5	25.4 62	9.1 78	39 75	32.8	2.1	33.0	-36 68	-5.7	13.2	-1.0	DEC

(con.)

Table 30. (Con.)

MAXIMUM DAILY TEMPERATURE — MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 246615 POLEBRIDGE — 1949-1978

	10-DAY AND MONTHLY PERIOD MEANS						10-DAY AND MONTHLY EXTREMES							
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR		HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	26.2	6.6	26.0	37.4 54	8.9 74		51 54	38.0	6.9	37.0	-10 63	11.3	9.8	10.0	JAN 1
JAN 11	27.1	8.9	29.0	39.3 53	6.5 50		48 73	37.4	6.9	39.0	-9 63	12.3	12.7	12.0	JAN 11
JAN 21	27.6	9.2	30.0	38.4 53	8.2 57		51 62	39.0	8.3	40.0	-5 57	13.8	12.0	17.0	JAN 21
FEB 1	34.1	6.9	34.0	46.4 54	14.8 75		58 63	44.2	6.2	44.0	2 50	22.0	9.8	23.0	FEB 1
FEB 11	36.5	4.3	37.0	46.4 77	25.4 56		54 77	44.9	4.7	45.0	2 56	27.4	8.8	29.0	FEB 11
FEB 21	37.6	6.7	38.0	47.6 73	15.9 62		55 58	45.1	6.5	46.0	7 57	29.8	9.1	32.0	FEB 21
MAR 1	37.0	5.9	37.0	46.4 65	19.3 51		62 53	46.9	6.1	48.0	0 51	24.8	9.7	26.0	MAR 1
MAR 11	41.6	4.0	42.0	51.7 72	34.2 67		61 72	50.7	5.4	51.0	11 67	31.7	7.4	32.0	MAR 11
MAR 21	44.9	5.8	45.0	55.5 78	33.9 65		65 78	54.8	6.2	55.0	9 55	34.5	9.6	38.0	MAR 21
APR 1	50.5	5.5	50.0	59.2 69	36.4 75		74 77	58.7	6.8	58.0	22 54	41.1	6.0	42.0	APR 1
APR 11	52.1	5.5	52.0	65.3 62	43.5 55		78 62	62.6	7.1	63.0	34 72	42.5	5.3	43.0	APR 11
APR 21	53.9	6.2	53.0	68.2 52	40.8 54		81 77	65.3	7.6	63.0	29 54	42.5	4.8	42.0	APR 21
MAY 1	59.8	6.2	57.5	74.3 66	51.3 64		85 76	70.7	7.0	68.5	38 56	47.8	6.5	46.5	MAY 1
MAY 11	64.4	5.4	64.0	74.8 73	49.7 74		84 73	74.8	6.0	76.0	43 74	52.5	5.1	51.0	MAY 11
MAY 21	66.1	5.8	64.0	80.6 58	56.3 78		86 58	76.1	6.0	77.0	40 78	54.7	7.4	54.0	MAY 21
JUN 1	69.6	5.7	68.0	81.5 70	59.6 54		89 77	78.5	6.1	77.5	46 76	58.3	6.8	59.0	JUN 1
JUN 11	71.2	5.6	69.0	86.2 74	63.8 73		91 74	81.3	5.9	80.0	44 76	60.0	7.2	59.0	JUN 11
JUN 21	72.3	5.5	71.0	82.1 61	61.2 69		91 55	82.5	5.5	81.5	48 71	60.4	6.8	59.0	JUN 21
JUL 1	77.4	5.6	77.0	87.8 68	65.4 55		95 73	85.8	5.5	86.0	54 55	66.9	6.3	65.0	JUL 1
JUL 11	80.6	5.4	81.0	93.0 60	69.9 72		100 60	88.8	4.6	88.0	58 78	71.0	7.8	70.0	JUL 11
JUL 21	82.3	4.1	82.0	91.3 60	74.0 49		99 65	90.0	3.3	90.0	57 75	71.4	7.5	74.0	JUL 21
AUG 1	82.2	4.7	83.0	90.0 71	73.8 62		101 61	90.3	4.3	90.0	55 76	71.7	6.8	73.0	AUG 1
AUG 11	80.1	6.8	80.5	97.0 67	67.3 68		99 67	87.4	5.1	88.5	55 68	71.3	9.3	72.5	AUG 11
AUG 21	75.1	7.0	74.0	88.9 67	64.3 75		102 69	85.7	6.5	85.0	53 78	64.4	7.6	64.5	AUG 21
SEP 1	73.8	6.8	73.0	91.3 67	60.3 64		99 67	83.2	6.7	82.5	50 75	62.0	6.8	62.5	SEP 1
SEP 11	67.7	6.7	67.0	78.4 67	48.2 65		90 69	78.5	7.1	78.5	38 65	55.0	7.9	55.0	SEP 11
SEP 21	64.4	8.9	63.0	83.7 67	50.2 72		90 67	74.6	7.8	75.5	40 72	53.4	10.5	50.0	SEP 21
OCT 1	59.4	6.1	58.0	70.0 52	48.8 59		85 55	71.3	6.7	72.0	35 59	48.1	7.5	48.0	OCT 1
OCT 11	54.8	6.2	54.0	65.9 63	43.6 51		73 58	64.0	6.6	65.0	31 51	44.3	6.1	45.0	OCT 11
OCT 21	48.1	6.3	48.5	59.9 65	37.1 61		70 69	58.2	6.7	59.5	21 57	39.1	7.6	40.5	OCT 21
NOV 1	43.1	4.9	43.0	50.2 75	27.6 73		64 75	53.1	5.5	52.0	14 73	34.0	7.2	35.0	NOV 1
NOV 11	36.5	6.3	37.0	44.1 54	15.9 55		56 53	45.6	4.9	45.0	0 55	27.6	9.7	31.0	NOV 11
NOV 21	34.4	4.4	34.0	43.2 49	26.5 75		56 54	44.4	5.0	44.0	11 75	23.3	6.7	24.0	NOV 21
DEC 1	31.4	5.6	32.0	39.6 65	10.3 72		52 65	42.1	4.9	42.0	-2 56	20.3	10.2	23.0	DEC 1
DEC 11	29.7	7.0	29.5	40.1 76	14.6 64		50 76	40.0	4.4	40.0	-9 64	19.8	11.3	20.5	DEC 11
DEC 21	29.2	6.8	30.5	38.6 50	9.7 68		49 63	39.6	5.5	40.0	-13 68	17.2	9.9	21.0	DEC 21
MONTH															MONTH
JAN	27.0	5.7	27.0	37.0 53	13.3 50		51 62	43.4	4.0	43.0	-10 63	5.3	9.5	4.0	JAN
FEB	36.0	3.6	36.0	42.8 63	28.9 75		58 63	49.4	3.7	50.0	2 56	18.5	8.8	19.0	FEB
MAR	41.3	3.4	41.0	47.3 69	34.3 55		65 78	55.9	5.7	56.0	0 51	22.0	9.6	23.0	MAR
APR	52.2	4.1	52.0	59.5 52	44.7 54		81 77	67.5	6.8	66.5	22 54	37.8	4.7	38.5	APR
MAY	63.5	4.0	63.0	75.1 58	56.9 78		86 58	79.0	4.1	79.5	38 56	46.0	4.5	45.0	MAY
JUN	71.1	3.6	71.0	81.0 61	64.2 76		91 74	85.8	3.4	86.0	44 76	54.9	4.9	55.0	JUN
JUL	80.2	3.4	79.0	89.2 60	74.8 72		100 60	91.7	3.3	91.0	54 55	63.9	5.5	64.0	JUL
AUG	79.0	5.1	77.5	91.2 67	70.5 75		102 69	91.8	4.3	91.5	53 78	63.1	6.7	64.0	AUG
SEP	68.6	5.8	68.5	84.5 67	54.3 65		99 67	84.2	5.9	83.5	38 65	48.5	6.8	46.0	SEP
OCT	53.9	4.3	53.0	63.6 52	46.8 51		85 55	72.6	5.2	72.0	21 57	37.8	6.6	37.0	OCT
NOV	38.0	3.5	38.0	44.8 49	28.5 55		64 75	53.8	5.0	53.0	0 55	21.0	8.8	23.0	NOV
DEC	30.1	3.7	31.0	35.5 57	21.1 51		52 65	44.5	4.3	45.0	-13 68	10.5	10.3	13.0	DEC

(con.)

MINIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 246615 POLEBRIDGE 1949-1978

	10-DAY AND MONTHLY PERIOD MEANS						10-DAY AND MONTHLY EXTREMES							
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR		HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	5.5	9.6	7.0	24.2 54	-13.6 73		34 53	24.2	8.0	26.0	-42 59	-17.1	12.6	-1.0	JAN 1
JAN 11	8.0	13.5	14.0	28.0 53	-18.9 50		36 74	25.6	8.7	27.0	-45 54	-14.1	19.1	-1.0	JAN 11
JAN 21	6.5	13.4	9.0	28.7 53	-19.3 63		34 60	26.2	8.7	29.0	-46 57	-17.5	17.8	-1.0	JAN 21
FEB 1	10.3	9.0	12.0	24.1 61	-12.7 75		39 63	27.6	7.1	29.0	-40 50	-10.4	14.2	-1.0	FEB 1
FEB 11	13.9	8.0	15.0	24.2 61	-2.4 49		34 71	28.1	4.0	29.0	-40 56	-5.2	13.5	-1.0	FEB 11
FEB 21	12.7	9.3	14.0	24.9 58	-15.9 62		36 61	26.9	6.3	28.0	-33 62	-3.0	13.9	0.0	FEB 21
MAR 1	11.0	6.6	11.0	23.5 77	-8.4 51		35 66	28.5	6.0	30.0	-38 60	-8.9	11.9	-1.0	MAR 1
MAR 11	15.3	6.8	15.0	29.3 72	2.7 65		36 72	29.6	4.3	30.0	-34 56	-1.6	14.1	0.0	MAR 11
MAR 21	20.3	7.6	21.0	29.6 56	0.0 65		35 67	31.1	2.8	32.0	-32 55	5.2	15.8	12.0	MAR 21
APR 1	23.3	3.9	22.5	28.6 74	9.8 75		40 74	32.7	3.1	33.0	-6 75	13.4	6.8	14.0	APR 1
APR 11	25.1	3.5	25.0	30.2 69	14.3 51		39 64	34.2	3.1	34.0	-9 51	15.6	6.5	15.5	APR 11
APR 21	27.1	2.8	27.0	33.9 53	22.5 54		43 59	35.1	3.8	35.0	-2 51	18.3	5.5	19.5	APR 21
MAY 1	29.8	2.4	30.0	34.1 57	22.5 54		44 63	38.2	2.9	38.0	-5 54	21.6	5.8	23.0	MAY 1
MAY 11	31.9	2.0	32.0	35.6 49	25.9 63		46 57	39.2	3.9	38.5	19 53	25.5	3.0	26.0	MAY 11
MAY 21	34.1	3.0	34.0	39.6 58	24.9 64		49 61	43.0	4.6	43.0	20 64	25.9	3.0	25.5	MAY 21
JUN 1	38.0	3.4	37.0	43.9 57	31.3 51		59 52	47.3	5.0	47.0	21 51	29.4	3.2	29.5	JUN 1
JUN 11	38.3	2.5	37.0	43.7 65	33.7 55		55 74	47.0	3.9	46.5	24 73	30.4	3.4	30.0	JUN 11
JUN 21	39.3	2.9	38.5	45.2 70	35.3 67		55 55	47.8	3.5	48.0	24 49	31.4	3.2	31.0	JUN 21
JUL 1	40.2	3.0	39.0	47.5 78	35.0 59		60 75	48.4	3.5	48.0	27 73	32.9	4.5	32.0	JUL 1
JUL 11	41.7	2.7	41.0	47.5 55	36.8 62		62 67	50.9	4.8	51.0	28 62	33.8	3.3	33.0	JUL 11
JUL 21	40.9	3.0	40.0	45.5 77	34.3 63		57 58	50.0	3.8	50.0	27 68	33.4	3.5	34.0	JUL 21
AUG 1	40.8	3.7	40.0	51.4 76	34.4 69		58 71	48.5	4.4	48.0	29 57	33.6	4.3	32.0	AUG 1
AUG 11	38.6	3.1	38.0	42.9 72	32.3 70		54 65	46.3	5.1	48.0	26 73	31.5	3.3	31.0	AUG 11
AUG 21	38.1	3.2	38.5	43.8 54	31.0 55		55 71	47.1	4.4	47.5	26 69	30.0	3.1	29.5	AUG 21
SEP 1	35.1	3.2	34.0	43.4 78	25.9 62		54 67	44.7	4.5	44.5	18 62	27.3	3.4	27.0	SEP 1
SEP 11	32.2	4.2	31.0	41.0 59	23.7 50		53 59	42.1	6.0	41.5	14 57	24.2	5.0	25.0	SEP 11
SEP 21	31.3	3.1	30.0	39.2 69	24.7 60		60 67	40.8	5.3	40.0	17 60	24.3	3.7	24.5	SEP 21
OCT 1	28.2	3.4	27.0	38.6 51	22.6 78		47 51	37.7	4.8	38.0	10 50	19.6	4.0	19.0	OCT 1
OCT 11	26.4	4.3	26.0	35.7 50	17.9 69		45 55	36.1	5.1	36.0	8 49	17.8	4.9	18.0	OCT 11
OCT 21	25.0	4.7	25.0	32.5 73	16.3 71		45 63	35.5	4.9	35.5	-8 71	15.4	7.5	15.0	OCT 21
NOV 1	21.5	5.3	21.0	31.1 62	12.1 61		43 54	33.3	5.3	33.0	-9 59	9.0	9.1	10.0	NOV 1
NOV 11	19.1	8.7	21.0	32.3 54	-4.3 55		38 52	31.3	3.3	32.0	-38 59	4.5	14.2	7.0	NOV 11
NOV 21	17.1	6.0	18.0	28.0 49	1.9 52		39 49	31.0	4.1	32.0	-25 58	-0.8	11.0	0.0	NOV 21
DEC 1	13.3	9.1	14.5	25.5 65	-18.7 72		38 75	29.5	4.6	29.5	-38 72	-4.7	13.8	-0.5	DEC 1
DEC 11	12.6	9.7	13.0	30.1 62	-6.0 64		34 77	27.1	5.7	28.0	-39 64	-5.5	15.2	-1.0	DEC 11
DEC 21	10.9	10.1	12.0	28.0 50	-12.5 51		34 50	27.2	5.9	29.0	-43 78	-9.2	14.0	-1.0	DEC 21
MONTH															MONTH
JAN	6.6	8.6	7.0	23.7 53	-13.8 49		36 74	31.2	3.5	32.0	-46 57	-27.3	13.2	-1.0	JAN
FEB	12.3	5.1	12.0	24.1 61	1.7 49		39 63	32.0	2.7	32.0	-40 56	-17.6	13.2	-1.0	FEB
MAR	15.7	4.6	15.0	23.7 72	4.3 65		36 72	33.2	1.8	34.0	-38 60	-13.3	13.0	-1.0	MAR
APR	25.1	2.3	25.0	29.0 69	18.5 75		43 59	36.9	2.9	37.0	-9 51	10.8	7.1	12.0	APR
MAY	32.0	1.4	31.5	34.4 58	29.5 59		49 61	44.0	3.6	44.0	-5 54	20.6	5.4	21.0	MAY
JUN	38.5	1.9	38.0	42.6 70	34.9 51		59 52	51.0	3.3	51.0	21 51	27.8	2.5	28.0	JUN
JUL	40.9	1.7	40.0	44.9 75	38.1 69		62 67	53.4	3.5	53.0	27 73	30.2	2.7	30.0	JUL
AUG	39.2	2.4	38.0	44.5 76	33.7 55		58 71	50.7	3.4	51.0	26 73	28.7	2.2	29.0	AUG
SEP	32.8	2.4	32.0	37.6 59	29.3 62		60 67	47.1	4.2	47.0	14 57	21.8	3.9	22.0	SEP
OCT	26.5	3.1	27.0	31.8 50	21.3 76		47 51	39.7	4.0	40.0	-8 71	13.1	6.4	12.0	OCT
NOV	19.3	4.5	19.0	27.0 54	10.1 59		43 54	35.3	3.4	35.0	-38 59	-6.0	11.9	-1.0	NOV
DEC	12.2	5.9	12.0	22.6 62	-1.8 78		38 75	31.9	3.1	32.0	-43 78	-18.1	12.5	-1.0	DEC

(CON)

Table 30. (Con.)

MAXIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 247978 SUMMIT

1949-1978

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JAN 1	21.9	7.1	22.0	33.1 61	8.7 50
JAN 11	22.6	9.5	24.0	37.0 61	0.8 50
JAN 21	21.8	10.4	25.0	33.9 53	-3.1 69
FEB 1	29.4	7.4	28.5	42.6 63	6.5 75
FEB 11	29.3	5.3	29.0	41.6 77	16.5 56
FEB 21	30.1	9.3	30.5	45.9 73	-2.8 62
MAR 1	29.5	7.9	29.5	46.4 68	2.4 51
MAR 11	33.9	6.0	33.5	46.9 72	22.6 65
MAR 21	37.0	7.6	37.5	50.0 60	19.4 75
APR 1	43.0	6.2	43.0	54.1 76	24.0 75
APR 11	43.6	6.4	42.0	62.2 62	33.3 53
APR 21	45.4	7.7	45.0	62.0 52	28.0 54
MAY 1	50.8	6.4	49.5	63.9 66	39.6 56
MAY 11	55.7	5.6	55.0	65.6 49	41.4 66
MAY 21	58.3	6.0	57.0	73.3 58	46.5 78
JUN 1	62.0	6.5	59.0	74.3 70	52.4 50
JUN 11	63.7	6.4	62.0	81.2 74	55.4 54
JUN 21	64.9	5.4	64.0	75.5 74	55.6 69
JUL 1	69.7	5.3	70.0	79.5 70	57.4 55
JUL 11	72.8	5.3	72.0	85.7 60	65.2 72
JUL 21	74.6	3.8	74.0	83.7 60	68.5 49
AUG 1	74.1	5.2	73.0	84.9 61	63.7 75
AUG 11	72.7	6.6	72.0	85.9 67	59.2 78
AUG 21	67.8	6.7	67.0	79.2 70	57.2 64
SEP 1	64.9	6.8	63.5	77.8 67	45.7 64
SEP 11	58.9	7.0	59.5	70.1 60	40.6 65
SEP 21	56.8	9.6	56.0	73.0 63	40.3 61
OCT 1	52.2	6.9	52.0	63.9 52	40.4 59
OCT 11	48.9	7.1	50.0	61.8 63	34.5 51
OCT 21	43.4	6.7	43.0	56.2 52	31.7 61
NOV 1	38.1	7.3	37.0	51.2 49	10.7 73
NOV 11	31.5	7.5	32.0	43.0 49	7.7 55
NOV 21	29.8	5.0	30.5	40.0 49	20.4 75
DEC 1	27.6	7.2	28.0	39.6 65	4.9 72
DEC 11	25.9	8.1	27.5	37.4 76	8.7 64
DEC 21	25.9	7.2	26.5	36.1 50	2.3 68
MONTH					
JAN	22.1	6.4	22.0	32.4 58	4.0 50
FEB	29.5	4.6	29.0	37.6 63	20.9 75
MAR	33.6	5.2	33.0	43.2 68	24.5 75
APR	44.0	4.7	43.0	52.9 52	34.9 75
MAY	55.0	4.2	54.5	66.6 58	49.2 75
JUN	63.5	4.3	62.5	74.5 61	57.1 51
JUL	72.5	2.8	71.0	82.2 60	67.4 58
AUG	71.4	5.1	70.0	82.8 61	62.3 75
SEP	60.2	5.7	59.0	71.2 67	45.4 65
OCT	48.2	4.7	47.0	61.9 53	40.8 51
NOV	33.2	4.7	33.0	44.7 49	21.8 73
DEC	26.5	4.3	27.0	32.5 50	19.1 68

10-DAY AND MONTHLY EXTREMES

HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
46 61	34.6	7.2	33.0	-24 66	3.9	13.8	5.0	JAN 1
48 61	34.7	8.6	35.0	-24 50	4.4	15.9	5.0	JAN 11
48 68	35.1	8.0	35.0	-25 50	2.9	16.0	4.0	JAN 21
53 62	40.9	5.7	41.5	-12 75	15.4	11.8	17.0	FEB 1
56 58	40.2	6.5	40.5	-16 56	14.7	12.9	16.5	FEB 11
54 58	38.9	9.1	40.0	-12 62	19.1	13.4	23.5	FEB 21
57 72	42.1	7.6	42.0	-21 51	12.5	14.1	14.0	MAR 1
60 60	45.4	7.5	45.5	-3 65	22.2	10.1	25.0	MAR 11
62 60	49.1	7.4	50.0	-7 55	24.0	12.1	28.0	MAR 21
65 77	53.2	6.6	53.0	-2 54	31.2	9.9	34.0	APR 1
72 62	54.8	7.3	54.0	17 53	31.5	7.3	33.0	APR 11
74 77	57.4	8.4	55.0	14 54	32.8	7.6	33.5	APR 21
76 49	61.8	7.5	60.0	18 54	37.9	7.9	38.0	MAY 1
76 49	66.5	5.7	65.5	28 55	41.7	6.7	42.0	MAY 11
78 72	69.1	5.8	69.0	34 51	45.8	7.2	45.0	MAY 21
84 77	71.9	6.6	70.0	33 50	49.5	7.6	50.0	JUN 1
88 68	75.0	6.2	75.0	38 73	51.6	7.7	50.0	JUN 11
86 74	75.9	5.7	76.5	40 51	51.4	6.8	51.0	JUN 21
86 54	79.0	4.6	80.0	44 56	59.0	6.9	60.0	JUL 1
93 60	81.8	5.4	83.0	46 71	61.2	7.7	62.0	JUL 11
91 60	82.9	3.4	83.0	49 75	64.3	6.8	65.0	JUL 21
96 61	83.6	5.1	84.0	50 78	62.3	6.9	63.0	AUG 1
90 61	80.2	4.8	80.0	46 78	62.0	8.9	63.0	AUG 11
96 69	80.1	6.4	82.0	43 65	54.6	8.1	52.0	AUG 21
92 67	77.5	7.1	79.0	35 64	50.1	7.7	51.0	SEP 1
85 59	72.2	8.5	73.0	20 70	43.4	9.1	43.0	SEP 11
82 57	68.8	9.2	70.5	21 65	42.8	10.6	43.0	SEP 21
82 57	66.8	7.2	67.0	20 57	37.8	9.2	37.0	OCT 1
71 63	61.2	7.5	63.5	19 51	35.4	7.7	36.0	OCT 11
67 52	56.1	6.3	57.0	16 71	31.7	8.4	32.0	OCT 21
64 75	49.8	6.4	49.0	-5 73	25.5	10.2	28.0	NOV 1
55 49	42.2	6.2	42.0	-16 55	20.4	12.7	23.0	NOV 11
53 50	41.2	5.8	42.0	0 75	16.1	9.1	18.0	NOV 21
49 59	40.0	5.4	40.0	-21 56	14.7	12.9	19.0	DEC 1
49 60	37.4	6.1	38.5	-24 64	13.3	15.0	19.0	DEC 11
47 54	37.6	5.4	36.5	-31 68	13.0	12.5	16.0	DEC 21
								MONTH
48 68	41.0	4.6	41.0	-25 50	-6.7	13.5	-1.0	JAN
56 58	45.7	4.3	45.0	-16 56	7.6	12.5	8.5	FEB
62 60	51.3	5.3	51.0	-21 51	8.4	13.5	10.0	MAR
74 77	60.7	7.4	60.0	-2 54	25.5	8.3	26.5	APR
78 72	71.1	4.9	72.0	18 54	35.2	6.0	36.0	MAY
88 68	79.7	4.4	79.5	33 50	45.3	6.0	45.5	JUN
93 60	84.5	3.4	84.0	44 56	55.2	6.1	54.0	JUL
96 69	85.3	4.6	85.0	43 65	53.4	7.6	52.0	AUG
92 67	79.1	6.2	80.0	20 70	37.4	8.8	36.0	SEP
82 57	68.7	5.0	68.0	16 71	28.7	7.0	29.5	OCT
64 75	50.7	5.6	50.0	-16 55	12.2	10.9	14.0	NOV
49 60	42.3	5.2	43.5	-31 68	1.7	14.7	2.5	DEC

(con.)

Table 20 (Con.)

MINIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 247978 SUMMIT

1949-1978

	10-DAY AND MONTHLY PERIOD MEANS						10-DAY AND MONTHLY EXTREMES							
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR		HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	5.7	10.4	8.0	22.4 61	-20.3 73		34 59	23.3	6.8	23.0	-55 59	-18.3	17.3	-1.0	JAN 1
JAN 11	6.1	13.2	8.0	23.5 76	-19.9 54		38 76	24.2	9.2	25.0	-53 54	-17.2	17.4	-1.0	JAN 11
JAN 21	5.3	14.4	9.0	25.9 53	-22.5 69		38 68	24.4	12.1	28.0	-45 63	-19.7	20.1	-1.0	JAN 21
FEB 1	13.5	9.2	13.0	27.3 61	-16.0 75		41 62	27.2	8.0	29.0	-30 76	-5.1	14.0	-1.0	FEB 1
FEB 11	12.8	8.1	13.0	26.2 77	-10.1 49		38 65	27.1	5.6	27.0	-40 56	-10.2	15.5	-1.0	FEB 11
FEB 21	12.7	11.6	14.5	28.3 68	-25.1 62		36 67	25.9	9.9	28.0	-43 62	-4.9	16.9	-1.0	FEB 21
MAR 1	10.0	8.5	9.5	26.2 68	-16.3 51		38 68	26.9	5.8	26.0	-42 60	-14.0	15.0	-1.0	MAR 1
MAR 11	13.9	8.1	14.0	33.4 72	-5.9 67		38 72	28.0	4.8	29.5	-38 65	-6.6	18.0	-1.0	MAR 11
MAR 21	17.9	8.7	19.5	34.8 78	-4.8 65		41 78	30.2	5.1	30.5	-41 65	-1.2	17.2	2.5	MAR 21
APR 1	21.4	4.7	21.5	29.5 49	7.4 75		47 60	33.7	5.0	33.5	-18 54	3.4	10.0	5.0	APR 1
APR 11	23.1	4.9	23.0	30.6 54	8.2 53		43 49	32.3	4.4	32.0	-12 53	10.4	11.5	14.0	APR 11
APR 21	24.3	4.4	24.0	32.0 53	13.5 67		43 65	34.2	4.8	34.0	-18 51	11.4	10.0	12.5	APR 21
MAY 1	28.0	2.8	28.0	33.1 58	21.4 67		43 67	35.8	3.6	35.5	2 67	19.2	5.7	20.5	MAY 1
MAY 11	30.6	2.7	30.5	36.5 56	25.5 66		53 70	40.0	5.2	40.5	12 53	23.3	4.3	24.0	MAY 11
MAY 21	32.5	2.2	32.0	37.4 58	28.5 71		49 69	41.3	3.8	41.0	17 60	23.8	3.7	23.0	MAY 21
JUN 1	35.8	3.2	35.0	41.6 77	28.0 51		54 60	45.6	5.0	46.0	15 51	27.3	3.9	28.0	JUN 1
JUN 11	37.3	2.5	37.0	42.0 74	29.9 69		55 49	45.9	3.5	45.0	18 69	28.6	4.2	29.0	JUN 11
JUN 21	39.0	3.3	39.0	44.4 74	28.9 51		59 70	48.2	5.6	47.5	22 71	30.4	4.2	30.0	JUN 21
JUL 1	40.1	3.7	40.0	48.7 78	31.7 71		58 67	48.3	4.2	47.0	22 71	31.0	4.7	30.0	JUL 1
JUL 11	41.5	3.4	41.0	49.0 55	34.1 62		59 78	51.6	3.8	52.0	25 73	32.8	4.3	33.0	JUL 11
JUL 21	41.1	4.1	39.0	50.0 77	32.5 73		59 75	51.4	4.4	51.0	25 73	31.3	4.4	31.0	JUL 21
AUG 1	41.0	3.2	40.0	50.2 76	35.5 54		60 55	51.5	4.4	52.0	26 77	31.1	4.1	31.0	AUG 1
AUG 11	39.6	3.1	38.0	46.4 78	33.1 51		59 60	49.5	4.6	50.0	21 70	29.9	4.8	30.0	AUG 11
AUG 21	38.5	3.2	38.0	44.7 61	32.7 49		57 58	48.2	4.4	47.0	21 69	29.3	4.3	30.0	AUG 21
SEP 1	35.7	4.3	35.0	46.9 78	27.5 62		58 76	48.0	5.6	48.5	10 62	25.6	5.7	25.0	SEP 1
SEP 11	33.2	4.2	33.0	40.1 66	24.0 50		58 53	45.9	5.9	46.0	6 57	21.7	6.4	22.5	SEP 11
SEP 21	32.7	4.3	32.0	41.7 78	23.0 72		56 76	44.0	6.4	45.0	12 72	22.3	5.4	23.5	SEP 21
OCT 1	30.7	5.1	31.0	40.0 76	20.8 57		54 60	43.9	5.6	44.0	2 70	17.3	7.9	17.0	OCT 1
OCT 11	29.4	4.9	29.0	37.0 55	13.0 69		57 61	40.0	6.3	40.0	2 49	18.3	7.7	19.0	OCT 11
OCT 21	26.2	4.7	26.5	33.8 65	17.5 61		50 66	37.1	5.1	37.0	-6 71	12.0	9.1	12.5	OCT 21
NOV 1	22.6	7.1	22.0	32.6 54	-1.2 73		46 56	34.8	5.4	34.0	-30 51	6.1	14.0	12.0	NOV 1
NOV 11	17.5	9.3	18.0	30.1 54	-12.1 55		40 76	30.5	5.4	31.0	-42 59	-0.1	14.9	-1.0	NOV 11
NOV 21	16.0	7.5	17.0	30.8 49	-0.7 70		40 57	29.7	5.2	29.5	-33 70	-2.0	14.3	-0.5	NOV 21
DEC 1	13.5	8.8	15.0	25.5 65	-14.2 72		39 50	28.7	4.6	30.0	-43 61	-8.7	16.8	-1.0	DEC 1
DEC 11	11.9	10.9	14.5	26.8 76	-12.4 64		37 76	26.5	7.0	27.0	-37 55	-5.7	15.3	-1.0	DEC 11
DEC 21	11.6	10.8	13.0	25.6 50	-19.6 68		38 63	26.2	7.6	26.5	-46 68	-7.2	16.7	-1.0	DEC 21
MONTH															MONTH
JAN	5.7	9.0	6.0	20.3 58	-16.1 50		38 76	30.4	5.3	31.0	-55 59	-29.6	14.5	-1.0	JAN
FEB	13.0	5.8	13.0	23.4 54	2.0 49		41 62	31.6	3.9	32.0	-43 62	-18.7	13.6	-1.0	FEB
MAR	14.1	5.9	12.0	26.2 78	0.1 65		41 78	32.7	3.7	32.0	-42 60	-20.4	14.1	-1.0	MAR
APR	22.9	2.7	22.0	28.1 49	18.1 51		47 60	37.6	3.8	37.0	-18 54	-0.3	10.1	-1.0	APR
MAY	30.4	1.4	29.5	33.6 58	28.1 68		53 70	43.3	3.6	42.0	2 67	17.7	5.3	18.5	MAY
JUN	37.4	1.9	37.0	40.2 74	31.5 51		59 70	51.2	3.8	51.0	15 51	25.3	3.8	26.0	JUN
JUL	40.9	3.0	40.0	46.7 75	35.5 62		59 78	54.1	3.1	54.0	22 71	28.8	2.9	28.0	JUL
AUG	39.7	2.3	38.0	46.5 76	36.5 49		60 55	53.4	3.6	55.0	21 70	27.0	3.4	26.0	AUG
SEP	33.9	3.2	33.0	41.8 78	27.5 65		58 76	50.8	4.8	51.0	6 57	18.4	5.5	18.0	SEP
OCT	28.7	3.0	29.0	33.5 76	22.6 69		57 61	45.8	4.6	45.0	-6 71	9.1	7.7	10.0	OCT
NOV	18.7	5.3	19.0	30.0 49	2.9 55		46 56	36.5	4.1	36.0	-42 59	-0.6	14.4	-1.0	NOV
DEC	12.3	6.0	13.5	21.1 57	1.4 68		39 50	31.9	3.8	31.5	-46 68	-21.3	14.8	-1.0	DEC

(con.)

Table 30. (Con.)

MAXIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240206 DESERT MTN LO

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	17	65.7	5.9	67.0	75.7 68	54.7 55 M
JUL 11	20	71.0	5.0	70.0	81.0 60	61.3 63
JUL 21	20	72.0	4.2	72.5	78.6 59	64.0 70
AUG 1	20	71.2	4.8	71.5	80.4 61	61.9 64
AUG 11	20	71.0	6.0	69.5	83.7 67	61.8 64
AUG 21	18	64.5	7.5	63.5	76.0 70	52.7 64
MONTH						
JUL	19	69.9	2.7	69.0	76.9 60 M	67.0 66
AUG	18	69.0	5.1	67.5	77.7 61	58.6 64

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	83 68	75.0	5.0	77.0	44 66	54.8	6.8	53.0	JUL 1
JUL 11	88 53	78.8	4.3	79.0	45 63	61.4	7.4	62.0	JUL 11
JUL 21	85 60	79.3	3.4	80.0	49 55	62.2	6.1	63.0	JUL 21
AUG 1	90 61	79.0	4.4	80.5	47 56	60.9	6.1	62.0	AUG 1
AUG 11	86 67	76.9	5.3	76.5	43 64	61.6	9.8	62.5	AUG 11
AUG 21	94 69	76.5	7.8	76.0	41 60	53.1	9.4	50.5	AUG 21
MONTH									MONTH
JUL	88 53	81.3	2.9	80.0	44 66	53.3	6.0	52.0	JUL
AUG	94 69	81.8	5.1	82.0	41 60	52.2	8.6	50.0	AUG

MINIMUM DAILY TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240206 DESERT MTN LO

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	17	45.1	4.8	45.0	54.7 68	36.3 55 M
JUL 11	20	50.3	4.7	49.5	61.4 60	42.9 68
JUL 21	20	50.0	3.1	49.0	56.8 60 M	45.6 70
AUG 1	20	50.4	3.7	51.0	57.2 61	42.4 57
AUG 11	20	49.9	5.0	49.0	62.6 67	43.0 59
AUG 21	18	44.8	5.0	43.5	53.3 61	36.8 60 M
MONTH						
JUL	19	48.8	2.6	48.0	56.5 60 M	45.2 62
AUG	18	48.4	3.5	48.0	55.5 61	42.6 64

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	66 68	54.8	5.6	55.0	32 68	36.6	3.4	37.0	JUL 1
JUL 11	67 60	58.9	5.1	59.5	35 57	41.3	4.9	39.0	JUL 11
JUL 21	64 59	58.4	3.6	58.0	32 59	40.1	4.2	39.0	JUL 21
AUG 1	73 61	59.3	4.9	59.0	35 57	41.4	3.3	42.0	AUG 1
AUG 11	65 67	57.4	5.1	58.0	35 66	40.9	5.3	40.0	AUG 11
AUG 21	68 69	55.2	6.8	54.5	31 51	36.3	4.5	35.0	AUG 21
MONTH									MONTH
JUL	67 60	61.4	3.5	61.0	32 68	36.1	2.8	37.0	JUL
AUG	73 61	61.8	4.8	62.0	31 51	35.9	3.9	35.0	AUG

Table 31.--Frequency distribution of daily maximum and minimum temperatures at West Glacier, Polebridge, and Summit; based on years 1949-78 and 24-hour periods ending about 5 p.m., m.s.t. Also, July-August frequencies at Desert Mountain Lookout; based on 1951-70

MAXIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN LO 1951-1970

		TEMPERATURE VALUES																					
PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JUL 1										12	24	97	91	218	145	194	176	42					JUL 1
JUL 11											5	15	30	151	206	236	236	95	25				JUL 11
JUL 21											5	5	46	97	162	264	301	106	14				JUL 21
AUG 1											5	20	35	120	225	220	215	135	15	10			AUG 1
AUG 11										5	10	26	20	97	245	260	194	133	10				AUG 11
AUG 21										52	52	78	130	146	156	193	89	83	10	10			AUG 21
MONTH																							MONTH
JUL										3	10	34	53	150	172	234	243	84	14				JUL
AUG										19	22	41	61	121	209	224	167	117	12	7			AUG

MINIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN LO 1951-1970

		TEMPERATURE VALUES																					
PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JUL 1								79	152	261	218	127	115	42	6								JUL 1
JUL 11									85	156	226	271	136	106	20								JUL 11
JUL 21								5	65	162	199	310	199	60									JUL 21
AUG 1									60	126	291	221	206	75	10	10							AUG 1
AUG 11									66	184	230	255	143	107	15								AUG 11
AUG 21								83	172	250	198	172	68	52	5								AUG 21
MONTH																							MONTH
JUL								24	97	188	214	245	153	71	9								JUL
AUG								27	99	186	240	216	140	78	10	3							AUG

(con.)

Table 31. (Con.)

MAXIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 248809 WEST GLACIER 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	7	13	64	87	47	110	187	258	157	60	10												JAN 1
JAN 11	30	27	40	60	50	67	147	280	203	77	20												JAN 11
JAN 21	21	58	55	45	58	76	109	188	285	73	33												JAN 21
FEB 1		3	3	43	47	80	73	237	317	140	50	7											FEB 1
FEB 11		3	3	13	10	40	87	223	380	180	53	7											FEB 11
FEB 21			8	16	32	32	57	162	324	206	146	12	4										FEB 21
MAR 1		3	10	7	23	33	113	160	297	190	113	27	20	3									MAR 1
MAR 11				3	7	10	20	77	243	357	177	90	17										MAR 11
MAR 21				6	9	12	24	21	148	306	197	161	91	24									MAR 21
APR 1						3		3	40	210	253	193	183	80	27	7							APR 1
APR 11								7	60	157	227	217	140	103	63	23	3						APR 11
APR 21								10	10	113	200	210	180	100	100	40	37						APR 21
MAY 1									10	37	110	157	173	173	140	133	47	20					MAY 1
MAY 11										7	67	107	160	143	223	113	137	43					MAY 11
MAY 21											15	67	145	188	209	191	124	48	12				MAY 21
JUN 1											7	43	80	153	223	193	173	87	40				JUN 1
JUN 11											3	17	74	152	195	178	199	111	64	7			JUN 11
JUN 21											3	37	67	110	190	187	143	147	110	7			JUN 21
JUL 1											3	3	17	57	120	187	190	220	167	37			JUL 1
JUL 11													7	20	67	150	173	247	260	73	3		JUL 11
JUL 21													3	30	30	79	176	321	312	48			JUL 21
AUG 1														17	50	123	200	263	253	83	10		AUG 1
AUG 11													20	60	67	90	233	267	177	73	13		AUG 11
AUG 21												30	61	103	152	145	197	167	115	24	6		AUG 21
SEP 1											3	33	67	140	153	210	207	103	60	23			SEP 1
SEP 11									3	17	27	90	153	150	157	210	137	40	17				SEP 11
SEP 21									7	30	83	170	157	113	163	150	97	23	7				SEP 21
OCT 1								3	20	63	140	183	170	167	173	73	7						OCT 1
OCT 11								10	17	83	213	247	193	170	67								OCT 11
OCT 21						3	9	36	97	188	248	230	115	70	3								OCT 21
NOV 1					10	7	27	97	203	347	170	90	40	10									NOV 1
NOV 11		13	13	10	13	17	60	157	353	257	73	23	10										NOV 11
NOV 21				17	20	40	123	263	303	157	53	23											NOV 21
DEC 1	3	13	23	17	43	53	137	330	240	100	23	17											DEC 1
DEC 11	7	10	20	23	63	87	160	253	297	70	10												DEC 11
DEC 21	18	3	6	18	76	79	185	321	161	94	36	3											DEC 21
MONTH																							MONTH
JAN	19	33	53	64	52	84	146	240	217	70	22												JAN
FEB		2	5	25	30	52	73	210	341	174	79	8	1										FEB
MAR		1	3	5	13	18	52	84	227	285	163	95	44	10									MAR
APR						1		7	37	160	227	207	168	94	63	23	13						APR
MAY									3	14	62	109	159	169	191	147	103	38	4				MAY
JUN											4	32	74	138	203	186	172	115	71	4			JUN
JUL											1	1	9	35	71	137	180	265	248	53	1		JUL
AUG												11	28	61	91	120	210	230	180	59	10		AUG
SEP									3	16	38	98	126	134	158	190	147	56	28	8			SEP
OCT						1	3	17	46	114	202	220	158	133	78	24	2						OCT
NOV		4	4	9	14	21	70	172	287	253	99	46	17	3									NOV
DEC																							DEC

MINIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 248809 WEST GLACIER 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	194	64	80	161	104	161	147	90															JAN 1
JAN 11	180	63	60	123	97	140	187	133	17														JAN 11
JAN 21	215	73	58	106	115	112	170	145	6														JAN 21
FEB 1	103	43	87	130	140	153	187	157															FEB 1
FEB 11	60	33	93	83	120	143	277	187	3														FEB 11
FEB 21	73	45	57	113	126	186	223	174	4														FEB 21
MAR 1	73	33	73	163	147	180	180	143	7														MAR 1
MAR 11	40	20	53	123	77	223	210	230	23														MAR 11
MAR 21	30	24	12	33	73	188	318	291	30														MAR 21
APR 1		3	7	20	60	180	320	333	77														APR 1
APR 11			3	10	20	173	343	317	117	17													APR 11
APR 21			3		13	83	280	377	183	60													APR 21
MAY 1				3		13	203	297	330	130	20	3											MAY 1
MAY 11							87	313	357	210	30		3										MAY 11
MAY 21							61	188	330	227	164	27	3										MAY 21
JUN 1						3	7	97	243	273	297	63	17										JUN 1
JUN 11							7	51	165	316	354	74	34										JUN 11
JUN 21								27	177	367	233	157	37	3									JUN 21
JUL 1								17	103	303	317	190	63	7									JUL 1
JUL 11								7	73	243	363	200	90	23									JUL 11
JUL 21								6	70	285	339	203	88	9									JUL 21
AUG 1									70	240	360	247	70	13									AUG 1
AUG 11								10	120	320	303	197	40	10									AUG 11
AUG 21								39	167	324	267	155	42	6									AUG 21
SEP 1							23	140	257	300	173	77	27		3								SEP 1
SEP 11					3	17	93	210	270	177	173	47	10										SEP 11
SEP 21						7	107	270	293	207	100	10	3	3									SEP 21
OCT 1					3	43	193	357	213	140	43	7											OCT 1
OCT 11					20	90	273	277	210	120	10												OCT 11
OCT 21		3		3	48	155	245	318	133	88	6												OCT 21
NOV 1		3	17	43	107	183	273	243	110	20													NOV 1
NOV 11	37	30	37	43	73	143	247	290	97	3													NOV 11
NOV 21	17	20	43	110	100	223	233	220	30	3													NOV 21
DEC 1	70	27	67	100	120	183	257	163	13														DEC 1
DEC 11	70	70	67	107	100	193	187	200	7														DEC 11
DEC 21	79	45	61	148	139	152	212	161	3														DEC 21
MONTH																							MONTH
JAN	197	67	66	129	105	137	168	124	8														JAN
FEB	79	40	80	109	129	159	229	172	2														FEB
MAR	47	26	45	104	98	197	239	224	20														MAR
APR		1	4	10	31	146	314	342	126	26													APR
MAY				1		4	115	263	339	190	74	11	2										MAY
JUN						1	4	58	195	319	294	98	29	1									JUN
JUL								10	82	277	340	198	81	13									JUL
AUG								17	120	296	309	198	51	10									AUG
SEP					1	8	74	207	273	228	149	44	13	1	1								SEP
OCT		1		1	25	98	238	317	184	115	19	2											OCT
NOV	18	18	32	66	93	183	251	251	79	9													NOV
DEC	73	47	65	119	120	175	218	174	8														DEC

(con.)

Table 31. (Con.)

MAXIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 246615 POLEBRIDGE 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	14	10	66	114	69	97	190	190	155	86	7	3											JAN 1
JAN 11	41	28	34	86	45	83	172	186	183	117	24												JAN 11
JAN 21	19	66	53	44	66	78	116	176	251	78	50	3											JAN 21
FEB 1		3	14	31	59	55	117	152	255	210	55	41	7										FEB 1
FEB 11		3		7	17	31	97	148	359	217	100	21											FEB 11
FEB 21			13	25	21	25	46	143	286	214	172	50	4										FEB 21
MAR 1		3	14	10	28	34	97	138	234	241	145	31	21	3									MAR 1
MAR 11				3	10	10	21	83	238	293	214	83	41	3									MAR 11
MAR 21			3	3	3	16	28	41	110	277	255	123	88	47	6								MAR 21
APR 1						4	4	14	32	146	304	168	193	86	43	7							APR 1
APR 11								11	47	115	280	172	161	122	57	29	7						APR 11
APR 21							4	7	29	114	218	207	132	129	89	43	18	11					APR 21
MAY 1									3	43	113	180	177	133	150	117	63	17	3				MAY 1
MAY 11										7	60	110	153	157	200	150	117	47					MAY 11
MAY 21										6	27	67	145	185	191	188	118	58	15				MAY 21
JUN 1											7	30	67	197	187	201	177	87	47				JUN 1
JUN 11										3		17	57	157	233	173	173	113	60	13			JUN 11
JUN 21											3	20	64	134	164	187	164	157	100	7			JUN 21
JUL 1												3	10	69	90	173	225	218	149	59	3		JUL 1
JUL 11													10	17	52	152	183	231	241	97	14	3	JUL 11
JUL 21													6	16	56	41	176	251	326	103	25		JUL 21
AUG 1													3	13	33	113	173	237	243	153	27	3	AUG 1
AUG 11													7	63	63	93	193	257	200	90	33		AUG 11
AUG 21												9	64	61	179	161	179	158	103	70	12	6	AUG 21
SEP 1												20	53	123	143	183	210	103	113	40	10		SEP 1
SEP 11									3	13	23	57	113	173	160	170	150	107	23	7			SEP 11
SEP 21										37	93	90	137	127	123	163	133	73	20	3			SEP 21
OCT 1									24	59	110	138	176	134	141	145	69		3				OCT 1
OCT 11								10	31	79	183	190	183	141	141	41							OCT 11
OCT 21							3	13	42	104	162	244	185	136	91	16	3						OCT 21
NOV 1					3	7	10	31	76	166	266	252	86	79	24								NOV 1
NOV 11		17	7	14	14	21	55	186	303	231	117	31	3										NOV 11
NOV 21				24	21	66	128	246	239	180	66	28	3										NOV 21
DEC 1	13	17	23	13	33	57	151	281	254	104	43	10											DEC 1
DEC 11	7	20	17	33	70	103	150	237	217	127	17	3											DEC 11
DEC 21	18	9	15	52	49	131	155	219	237	88	27												DEC 21
MONTH																							MONTH
JAN	24	36	51	80	60	86	158	184	198	93	28	2											JAN
FEB		2	9	21	33	38	89	148	301	214	105	37	4										FEB
MAR		1	6	6	13	20	48	86	192	271	206	80	51	19	2								MAR
APR						1	2	11	36	125	267	182	162	112	63	26	8	4					APR
MAY									1	18	66	117	158	159	181	153	100	41	6				MAY
JUN										1	3	22	62	163	195	187	171	119	69	7			JUN
JUL												1	9	33	66	119	194	234	242	87	14	1	JUL
AUG												3	26	46	95	124	182	215	180	103	24	3	AUG
SEP									1	17	39	56	101	141	142	172	164	94	52	17	3		SEP
OCT						1	5	18	54	101	180	171	164	122	98	62	23		1				OCT
NOV		6	2	14	14	32	71	169	236	226	145	48	29	8									NOV
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	152	245	236	106	29	4											DEC

Table 31. (Con.)

MINIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 246615 POLEBRIDGE 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	345	66	103	124	121	117	76	48															JAN 1
JAN 11	297	66	76	117	121	90	110	103	21														JAN 11
JAN 21	320	72	78	119	88	110	129	85															JAN 21
FEB 1	183	114	138	124	114	117	124	72	14														FEB 1
FEB 11	138	100	83	128	117	155	190	90															FEB 11
FEB 21	164	118	101	118	122	122	185	63	8														FEB 21
MAR 1	193	110	107	162	114	114	107	86	7														MAR 1
MAR 11	117	66	83	131	176	179	134	97	17														MAR 11
MAR 21	60	28	38	82	147	210	257	166	13														MAR 21
APR 1	7	14	21	79	146	243	261	196	29	4													APR 1
APR 11	7		7	50	125	232	314	200	64														APR 11
APR 21	4		4	14	82	214	339	229	96	18													APR 21
MAY 1	3		3		17	133	330	317	153	43													MAY 1
MAY 11					3	47	263	353	260	67	7												MAY 11
MAY 21						48	179	315	258	142	58												MAY 21
JUN 1						7	97	237	250	240	123	40	7										JUN 1
JUN 11						7	60	220	270	277	133	27	7										JUN 11
JUN 21						3	40	190	283	283	167	30	3										JUN 21
JUL 1							38	107	329	273	204	45		3									JUL 1
JUL 11							10	90	262	321	214	79	21	3									JUL 11
JUL 21							16	122	292	304	179	72	16										JUL 21
AUG 1							7	147	280	290	193	60	23										AUG 1
AUG 11							47	193	353	247	100	60											AUG 11
AUG 21							91	185	309	245	130	36	3										AUG 21
SEP 1					7	27	163	320	237	143	87	17											SEP 1
SEP 11				3	30	84	264	261	194	104	47	13											SEP 11
SEP 21					17	103	317	263	183	87	27			3									SEP 21
OCT 1				7	86	210	303	210	110	66	7												OCT 1
OCT 11			7	38	138	210	262	200	100	41	3												OCT 11
OCT 21	6	3	13	101	107	198	266	188	84	29	3												OCT 21
NOV 1	10	52	45	110	166	203	197	166	38	14													NOV 1
NOV 11	86	59	55	93	117	128	279	155	28														NOV 11
NOV 21	100	48	72	134	155	186	162	117	24														NOV 21
DEC 1	140	100	97	117	140	140	154	100	10														DEC 1
DEC 11	180	100	97	123	123	120	127	130															DEC 11
DEC 21	220	73	104	125	149	107	134	88															DEC 21
MONTH																							MONTH
JAN	320	68	86	120	109	106	106	79	7														JAN
FEB	161	110	108	123	117	132	165	76	7														FEB
MAR	121	67	75	123	146	169	169	118	12														MAR
APR	6	5	11	48	118	230	305	208	63	7													APR
MAY	1		1		6	75	255	328	225	86	23												MAY
JUN						6	66	216	268	267	141	32	6										JUN
JUL							21	107	294	300	198	66	12	2									JUL
AUG							49	175	314	260	141	52	9										AUG
SEP				1	18	71	248	281	205	111	53	10		1									SEP
OCT	2	1	7	50	110	206	277	199	98	45	5												OCT
NOV	66	53	57	113	146	172	213	146	30	5													NOV
DEC	101	91	99	122	138	122	138	106	3														DEC

(con.)

Table 31. (Con.)

MAXIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 247978 SUMMIT 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	52	41	59	72	110	166	228	145	83	31	14												JAN 1
JAN 11	93	17	41	62	93	169	155	200	90	62	17												JAN 11
JAN 21	107	38	78	47	72	110	172	229	75	53	19												JAN 21
FEB 1	17	27	20	40	50	87	200	223	190	80	57	10											FEB 1
FEB 11	17	17	23	23	43	90	227	287	133	100	27	10	3										FEB 11
FEB 21	32	12	40	16	12	109	174	231	178	121	61	12											FEB 21
MAR 1	40	10	13	47	60	93	133	230	163	143	23	33	10										MAR 1
MAR 11	7	3	10	27	37	50	120	267	223	127	70	43	13	3									MAR 11
MAR 21	9	9	18	18	15	24	88	188	197	185	127	82	33	6									MAR 21
APR 1	3			3	3	23	50	67	167	237	207	133	80	23	3								APR 1
APR 11					13	23	27	97	187	227	123	157	73	40	20	13							APR 11
APR 21				7		20	37	90	157	163	160	170	87	63	27	20							APR 21
MAY 1					3		13	37	83	140	157	193	160	130	53	17	13						MAY 1
MAY 11							7	17	53	77	113	147	217	160	117	77	17						MAY 11
MAY 21								3	9	66	110	160	204	182	132	91	44						MAY 21
JUN 1								7	10	17	70	127	170	173	203	100	83	40					JUN 1
JUN 11									3	10	50	123	163	177	190	137	80	47	20				JUN 11
JUN 21										20	50	80	143	177	187	177	90	63	13				JUN 21
JUL 1										7	3	48	76	121	183	255	186	110	10				JUL 1
JUL 11											3	24	24	93	166	259	217	145	52	17			JUL 11
JUL 21											3	6	25	47	116	219	326	213	38	6			JUL 21
AUG 1												17	28	100	128	224	207	193	83	17	3		AUG 1
AUG 11											10	14	62	83	152	200	252	145	72	10			AUG 11
AUG 21										9	28	94	94	160	135	185	141	116	34		3		AUG 21
SEP 1									17	23	40	97	143	130	193	147	113	80	7	10			SEP 1
SEP 11						7	3	7	33	63	100	173	117	130	143	137	60	23	3				SEP 11
SEP 21						3	7	37	53	117	93	143	110	107	120	107	83	20					SEP 21
OCT 1						20	13	37	97	83	153	147	123	133	133	53	3	3					OCT 1
OCT 11					7	10	20	37	147	177	103	153	137	127	73	10							OCT 11
OCT 21					9	19	56	116	185	144	144	166	100	50	9								OCT 21
NOV 1	7	10		14	21	38	72	134	255	179	138	83	38	10									NOV 1
NOV 11	17	21	7	24	14	87	163	256	204	111	80	14	3										NOV 11
NOV 21		14	25	32	29	161	186	246	161	93	36	18											NOV 21
DEC 1	48	19	15	22	48	130	233	204	152	96	33												DEC 1
DEC 11	32	14	39	64	75	125	221	189	175	46	18												DEC 11
DEC 21	26	16	10	42	101	195	192	237	104	62	16												DEC 21
MONTH																							MONTH
JAN	85	32	60	60	91	147	185	192	82	49	17												JAN
FEB	21	19	27	27	37	94	202	248	166	99	47	11	1										FEB
MAR	18	8	14	30	37	55	113	227	195	153	75	54	19	3									MAR
APR	1			3	6	22	38	84	170	209	163	153	80	42	17	11							APR
MAY					1		7	18	48	94	126	166	194	158	101	62	25						MAY
JUN								2	4	16	57	110	159	176	193	138	84	50	11				JUN
JUL										2	3	26	41	86	154	244	246	158	33	8			JUL
AUG										3	13	43	62	116	138	202	198	150	62	9	2		AUG
SEP						3	3	14	34	68	78	138	123	122	152	130	86	41	3	3			SEP
OCT					5	16	30	64	144	135	134	156	120	102	71	21	1	1					OCT
NOV	8	15	10	23	21	94	140	212	207	128	85	38	14	3									NOV
DEC	35	16	21	43	76	152	214	211	142	68	22												DEC

MINIMUM DAILY TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 247978 SUMMIT 1949-1978

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JAN 1	321	62	79	148	148	138	66	38															JAN 1
JAN 11	355	62	55	62	145	159	90	62	10														JAN 11
JAN 21	348	60	56	82	113	157	110	60	16														JAN 21
FEB 1	180	57	83	107	153	170	147	90	7	7													FEB 1
FEB 11	183	63	87	77	137	253	123	70	7														FEB 11
FEB 21	190	40	93	109	138	194	134	89	12														FEB 21
MAR 1	223	97	80	117	120	210	93	43	17														MAR 1
MAR 11	157	67	60	110	207	170	120	100	10														MAR 11
MAR 21	100	39	48	88	106	288	182	109	33	6													MAR 21
APR 1	53	23	43	80	140	220	243	150	30	13	3												APR 1
APR 11	30	13	27	50	100	280	313	150	27	10													APR 11
APR 21	13	10	30	60	120	213	283	193	60	17													APR 21
MAY 1		3	13	17	37	163	323	320	97	27													MAY 1
MAY 11				7	20	90	353	273	167	70	17	3											MAY 11
MAY 21					13	66	229	335	226	103	28												MAY 21
JUN 1					3	30	148	265	285	164	67	37											JUN 1
JUN 11					7	7	80	227	328	251	80	17	3										JUN 11
JUN 21						10	51	195	269	283	148	30	13										JUN 21
JUL 1						3	55	138	245	297	200	55	7										JUL 1
JUL 11							28	125	226	299	201	97	24										JUL 11
JUL 21							54	155	215	247	209	92	28										JUL 21
AUG 1							62	159	193	245	221	79	38	3									AUG 1
AUG 11						10	66	183	214	279	166	69	14										AUG 11
AUG 21						19	103	163	229	295	132	44	16										AUG 21
SEP 1				3	13	47	157	257	217	143	100	43	20										SEP 1
SEP 11			7	13	47	80	173	233	220	140	53	23	10										SEP 11
SEP 21				7	43	123	187	240	173	110	93	20	3										SEP 21
OCT 1		10	7	31	86	103	200	217	148	128	48	21											OCT 1
OCT 11		14	10	34	55	86	279	269	145	72	31		3										OCT 11
OCT 21	10	10	29	52	97	156	269	211	97	65		3											OCT 21
NOV 1	59	38	28	93	52	169	272	176	79	31	3												NOV 1
NOV 11	100	42	62	111	111	228	194	114	35	3													NOV 11
NOV 21	121	64	43	132	150	218	157	86	25	4													NOV 21
DEC 1	170	56	59	130	144	196	156	78	11														DEC 1
DEC 11	193	64	93	132	150	157	125	68	18														DEC 11
DEC 21	182	71	84	143	133	227	84	62	13														DEC 21
MONTH																							MONTH
JAN	341	61	63	97	135	151	89	53	9														JAN
FEB	184	54	87	97	143	207	135	83	8	2													FEB
MAR	158	67	62	104	143	225	133	85	20	2													MAR
APR	32	16	33	63	120	238	280	164	39	13	1												APR
MAY		1	4	8	23	106	300	310	164	67	15	1											MAY
JUN					3	16	93	229	294	233	98	28	6										JUN
JUL						1	46	140	228	280	204	82	20										JUL
AUG						10	78	168	212	274	171	63	22	1									AUG
SEP			2	8	34	83	172	243	203	131	82	29	11										SEP
OCT	3	11	16	39	80	116	250	232	130	88	26	8	1										OCT
NOV	93	48	44	112	104	205	208	126	47	13	1												NOV
DEC	182	64	79	135	142	195	120	69	14														DEC

Table 32.--Mean temperature statistics; based on arithmetic average of daily maximum and minimum temperatures (table 30)

MEAN DAILY TEMPERATURE — MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 248809 WEST GLACIER — 1949-1978

	10-DAY AND MONTHLY PERIOD MEANS					10-DAY AND MONTHLY EXTREMES							
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD BEGI
JAN 1	19.5	7.7	20.5	33.4 54	2.8 74	40 53	31.0	5.9	32.5	-14 59	4.1	10.9	4.5	JAN
JAN 11	21.2	9.7	24.0	34.4 53	-1.6 50	42 74	31.7	6.9	33.0	-18 54	6.6	13.9	5.5	JAN
JAN 21	20.1	10.3	22.0	34.2 53	-0.7 57	40 71	31.5	8.2	34.0	-19 50	4.5	14.1	7.5	JAN
FEB 1	24.9	6.9	26.0	34.9 52	5.9 75	43 63	34.3	5.1	34.5	-16 50	11.5	12.2	12.0	FEB
FEB 11	27.5	5.2	28.0	36.7 77	15.1 56	40 77	35.6	2.7	36.0	-14 56	16.2	10.1	17.0	FEB
FEB 21	27.8	7.0	29.0	36.8 68	6.3 62	44 50	35.4	5.2	37.0	-5 62	18.8	10.5	20.5	FEB
MAR 1	27.2	5.4	27.0	39.2 68	9.4 51	46 68	36.4	4.1	36.5	-8 60	15.2	9.5	15.5	MAR
MAR 11	31.4	4.2	31.5	40.2 72	22.4 65	44 76	38.9	2.9	39.0	0 56	21.1	9.2	23.0	MAR
MAR 21	34.6	5.5	35.0	43.4 78	20.4 55	48 78	41.3	3.2	41.5	0 55	25.9	10.5	29.0	MAR
APR 1	38.6	3.1	38.0	44.3 60	29.3 75	54 77	44.5	3.6	44.0	11 54	31.4	5.3	33.0	APR
APR 11	40.1	3.1	39.5	46.9 62	35.3 53	58 62	47.3	4.5	47.5	18 51	33.2	4.6	34.0	APR
APR 21	42.8	3.8	42.0	51.9 77	34.2 54	58 52	49.5	4.6	49.5	24 51	35.8	4.9	36.0	APR
MAY 1	47.1	3.7	46.0	55.5 66	42.2 50	61 66	53.6	3.7	54.5	26 54	39.8	5.2	39.0	MAY
MAY 11	50.1	3.2	49.0	56.6 49	42.2 74	67 70	57.1	3.7	57.0	38 74	42.9	3.7	42.0	MAY
MAY 21	52.5	3.8	51.5	63.0 58	46.1 55	67 56	60.0	3.9	60.0	40 78	45.1	4.0	44.5	MAY
JUN 1	55.7	3.7	54.5	62.6 70	48.9 51	70 77	62.1	4.0	62.0	41 66	48.2	3.8	48.5	JUN
JUN 11	57.3	3.4	57.0	66.6 74	51.6 54	73 61	64.1	3.7	63.5	42 54	49.8	3.8	49.0	JUN
JUN 21	58.0	3.4	56.5	64.9 70	52.9 51	73 68	65.9	4.4	67.0	41 71	49.7	4.5	49.5	JUN
JUL 1	61.3	3.5	61.0	70.6 75	53.0 55	75 75	67.9	3.1	68.0	42 55	54.3	4.6	54.0	JUL
JUL 11	63.7	3.1	63.0	69.8 60	58.1 72	79 67	70.2	3.8	71.0	50 72	56.4	3.5	56.0	JUL
JUL 21	64.0	2.3	64.0	68.5 56	59.8 54	74 74	69.7	2.5	70.0	50 52	56.7	3.2	56.5	JUL
AUG 1	64.1	2.6	63.5	71.1 71	58.9 64	75 52	69.5	3.1	70.0	53 64	57.7	3.3	57.0	AUG
AUG 11	62.3	3.6	62.0	70.1 67	54.4 68	76 67	67.8	3.6	67.0	49 76	56.5	4.2	56.5	AUG
AUG 21	59.1	3.8	58.0	65.6 67	51.5 60	78 69	66.4	4.2	66.0	45 65	51.8	4.4	51.5	AUG
SEP 1	56.3	4.2	55.5	67.6 67	49.2 64	80 67	63.2	5.9	64.5	39 62	48.7	4.3	48.0	SEP
SEP 11	51.6	4.4	51.5	59.4 66	39.6 65	67 58	59.9	5.5	62.0	34 65	44.4	5.3	45.0	SEP
SEP 21	49.3	5.0	48.5	60.2 67	40.4 72	73 67	56.1	6.3	56.5	32 72	42.1	5.2	42.0	SEP
OCT 1	45.4	3.3	45.0	51.1 65	39.3 59	60 57	53.0	3.3	52.5	30 57	38.3	4.4	38.0	OCT
OCT 11	42.5	3.4	43.0	47.4 63	34.9 69	56 50	48.1	4.3	48.0	25 51	36.1	4.1	37.5	OCT
OCT 21	38.7	3.7	39.0	44.5 65	31.3 61	54 77	46.4	4.9	46.5	15 71	31.5	5.5	32.5	OCT
NOV 1	34.2	4.2	34.5	40.5 75	23.3 73	52 75	41.4	4.7	41.0	13 73	26.4	7.0	29.0	NOV
NOV 11	30.4	7.1	31.5	39.1 54	7.9 55	46 56	38.1	4.5	38.0	-10 59	21.2	10.5	24.5	NOV
NOV 21	28.6	4.0	28.5	36.6 49	20.7 75	47 62	37.3	4.3	37.0	0 77	17.7	8.0	19.0	NOV
DEC 1	25.7	6.5	27.0	34.4 65	1.6 72	43 75	35.3	3.8	35.0	-14 72	14.4	10.7	16.5	DEC
DEC 11	24.5	7.5	25.0	34.9 62	8.6 64	39 62	33.6	3.6	34.5	-19 64	14.1	11.8	15.5	DEC
DEC 21	24.1	7.1	25.5	33.4 50	3.6 68	40 58	33.8	5.0	34.5	-22 68	11.6	11.2	12.5	DEC
MONTH														MO
JAN	20.3	6.6	20.5	32.0 53	4.8 50	42 74	36.4	3.2	36.0	-19 50	-2.7	10.8	-1.0	N
FEB	26.6	3.8	26.5	32.8 61	19.0 49	44 50	38.0	2.6	38.0	-16 50	6.6	11.1	5.5	E
MAR	31.2	3.6	30.5	38.8 68	23.5 55	48 78	42.1	2.5	42.0	-8 60	12.7	10.1	12.5	R
APR	40.5	2.4	40.0	44.4 77	35.7 54	58 62	50.8	4.2	50.0	11 54	29.7	5.5	30.5	R
MAY	50.0	2.4	49.0	57.4 58	46.1 55	67 70	60.7	3.5	60.0	26 54	38.5	3.8	39.0	Y
JUN	57.0	2.3	56.5	62.6 61	52.6 51	73 68	67.8	3.4	68.0	41 71	46.1	2.9	47.0	N
JUL	63.0	1.6	62.0	67.7 75	60.2 72	79 67	71.8	2.6	71.0	42 55	52.4	3.2	53.0	L
AUG	61.7	2.6	61.0	66.7 67	56.6 64	78 69	70.8	3.2	70.5	45 65	51.3	3.7	51.5	G
SEP	52.5	3.5	52.0	61.7 67	44.3 65	80 67	64.4	5.2	65.0	32 72	40.2	4.5	39.0	P
OCT	42.1	2.2	42.0	46.3 65	38.3 70	60 57	53.6	2.8	53.0	15 71	30.9	5.2	32.0	T
NOV	31.0	3.4	30.5	37.0 54	22.1 55	52 75	42.9	3.7	42.5	-10 59	14.5	9.3	16.5	V
DEC	24.7	4.2	25.5	30.6 62	16.7 51	43 75	37.2	2.9	37.5	-22 68	4.5	11.6	6.0	C

(con.

Table 32. (Con.)

MEAN DAILY TEMPERATURE — MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 246615 POLEBRIDGE — 1949-1978

PRD. BEGINS	10-DAY AND MONTHLY PERIOD MEANS: MEAN	STD. DEV.	MEDIAN	HIGHEST AVG.YR	LOWEST AVG.YR	10-DAY AND MONTHLY EXTREMES: HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JAN 1	15.8	8.0	17.0	30.8 54	-2.1 74	41 53	30.3	7.3	32.0	-22 50	-2.1	10.3	-1.0	JAN 1
JAN 11	17.5	11.0	22.0	33.6 53	-6.2 50	40 61	30.6	7.9	32.0	-23 54	0.5	15.1	0.0	JAN 11
JAN 21	17.0	11.1	20.0	33.5 53	-5.3 57	41 60	31.8	6.2	34.0	-25 57	-0.8	14.6	0.0	JAN 21
FEB 1	22.2	7.6	23.0	32.9 61	1.1 75	47 63	34.6	5.5	35.0	-19 50	6.6	12.0	5.0	FEB 1
FEB 11	25.2	5.8	26.0	33.1 71	12.1 56	43 58	34.7	3.6	34.0	-19 56	11.9	11.1	14.0	FEB 11
FEB 21	25.1	7.7	27.0	34.9 58	0.0 62	41 57	34.1	5.7	35.0	-10 57	14.3	11.0	15.0	FEB 21
MAR 1	24.0	5.8	24.0	33.1 77	5.4 51	43 72	35.8	4.8	37.0	-13 60	9.7	10.1	11.0	MAR 1
MAR 11	28.5	4.9	28.0	40.5 72	19.1 65	47 72	37.9	3.5	37.0	-7 56	16.2	10.0	16.0	MAR 11
MAR 21	32.6	6.1	34.0	42.0 78	17.0 65	47 78	40.7	3.0	41.0	-4 65	22.0	11.9	26.0	MAR 21
APR 1	36.9	4.0	37.0	43.2 60	23.1 75	55 77	43.3	4.0	43.0	11 75	29.3	6.5	30.0	APR 1
APR 11	38.6	3.5	38.0	45.6 62	32.3 53	55 63	45.5	3.9	45.0	12 51	31.0	5.3	31.0	APR 11
APR 21	40.5	3.7	39.5	46.8 52	31.6 54	55 70	47.9	4.6	48.5	20 51	32.6	4.7	33.0	APR 21
MAY 1	44.8	3.6	43.5	52.4 66	40.2 54	58 76	51.4	3.9	51.0	17 54	37.4	5.5	37.5	MAY 1
MAY 11	48.1	2.9	47.5	53.8 49	40.6 74	63 56	54.6	3.8	55.0	36 74	41.4	3.4	40.0	MAY 11
MAY 21	50.1	3.9	50.0	60.1 58	44.2 64	65 66	56.8	4.0	56.5	33 60	42.4	4.7	42.0	MAY 21
JUN 1	53.8	3.4	53.0	60.8 72	46.5 51	70 70	60.3	4.8	60.5	39 76	46.6	4.0	48.0	JUN 1
JUN 11	54.8	3.3	54.0	64.1 74	50.2 76	69 74	61.7	3.5	62.0	39 76	47.6	3.6	48.0	JUN 11
JUN 21	55.8	3.2	55.0	63.4 70	50.6 51	71 55	63.0	3.6	62.5	39 71	48.2	3.3	49.0	JUN 21
JUL 1	58.8	3.5	58.0	66.4 75	51.9 71	70 75	64.7	3.2	65.0	45 55	52.1	3.9	52.0	JUL 1
JUL 11	61.1	3.4	61.0	67.6 60	56.0 82	79 67	67.7	4.3	67.0	46 78	54.3	4.0	54.0	JUL 11
JUL 21	61.6	2.3	61.0	65.5 60	56.4 54	73 59	67.4	2.8	68.0	49 55	54.3	2.9	54.0	JUL 21
AUG 1	61.5	2.9	61.0	69.3 71	56.9 56	72 76	66.7	3.4	67.0	47 64	54.7	3.7	54.5	AUG 1
AUG 11	59.4	3.3	58.0	68.2 67	54.3 78	72 61	64.7	3.2	64.5	48 76	53.7	3.9	53.0	AUG 11
AUG 21	56.6	3.5	55.0	63.3 61	51.4 78	73 69	63.9	4.2	63.0	45 76	49.8	3.4	49.0	AUG 21
SEP 1	54.4	3.7	53.0	64.9 67	47.1 65	75 67	61.3	5.0	62.0	37 62	47.1	4.0	47.0	SEP 1
SEP 11	49.9	4.3	49.5	56.9 67	39.4 65	67 66	57.1	5.1	56.0	32 70	42.5	5.6	43.0	SEP 11
SEP 21	47.8	4.8	47.5	59.3 67	39.5 72	72 67	54.1	5.4	54.5	32 72	40.9	5.4	40.5	SEP 21
OCT 1	43.3	3.3	43.0	49.4 63	37.9 59	60 65	51.3	4.3	51.0	26 70	36.1	4.8	37.0	OCT 1
OCT 11	40.6	3.5	41.0	46.4 63	33.2 69	53 67	47.2	3.8	48.0	24 49	33.1	4.2	33.0	OCT 11
OCT 21	36.6	4.3	36.0	44.2 62	27.8 61	52 55	44.6	4.6	44.5	10 71	28.3	6.6	30.0	OCT 21
NOV 1	32.3	4.6	32.0	39.6 75	20.5 73	51 78	41.2	4.4	40.0	6 51	22.9	8.2	25.0	NOV 1
NOV 11	27.8	7.3	29.0	38.2 54	5.8 58	43 62	37.0	3.6	37.0	-18 59	16.4	11.4	19.0	NOV 11
NOV 21	25.7	5.0	26.0	35.6 49	14.4 52	45 49	36.3	4.7	36.0	-7 58	11.8	8.9	12.0	NOV 21
DEC 1	22.4	7.2	23.0	32.6 65	-4.2 79	43 65	34.9	4.4	34.5	-19 72	8.2	11.6	12.0	DEC 1
DEC 11	21.2	8.1	22.0	33.9 66	4.3 64	37 77	32.3	4.2	33.0	-23 64	7.7	12.8	7.0	DEC 11
DEC 21	20.1	8.2	21.0	33.3 50	-0.1 61	39 56	32.3	5.3	34.0	-25 68	4.8	11.6	6.5	DEC 21
MONTH														MONTH
JAN	16.8	7.1	17.0	30.3 53	1.0 50	41 60	36.3	3.1	36.0	-25 57	-9.0	10.7	-1.0	JAN
FEB	24.1	4.1	24.0	31.8 61	15.6 49	47 63	38.4	4.3	38.0	-19 56	1.7	10.6	1.0	FEB
MAR	28.5	3.7	28.0	35.2 72	21.1 55	47 78	41.7	2.5	41.0	-13 60	6.9	10.5	9.0	MAR
APR	38.7	2.6	38.5	43.3 69	31.6 75	55 78	49.5	3.8	49.0	11 75	26.8	6.3	28.0	APR
MAY	47.8	2.4	47.0	54.7 58	44.4 53	65 66	57.9	3.1	57.5	17 54	36.4	4.9	38.0	MAY
JUN	54.8	2.3	54.0	60.0 70	50.3 76	71 55	65.5	2.7	65.5	39 76	44.7	3.2	45.0	JUN
JUL	60.5	1.6	60.0	64.5 60	57.7 72	79 67	69.5	2.9	69.0	45 55	50.6	2.9	51.0	JUL
AUG	59.1	2.6	58.0	64.5 67	55.4 64	73 69	68.0	3.0	68.0	45 76	49.4	2.9	49.0	AUG
SEP	50.7	3.3	50.5	60.4 67	42.9 65	75 67	62.1	5.0	62.0	32 72	38.3	4.5	37.0	SEP
OCT	40.2	2.3	40.0	44.6 65	36.7 71	62 55	51.8	3.9	51.0	10 71	27.6	6.1	30.0	OCT
NOV	26.6	3.8	26.0	35.9 54	19.6 55	51 78	42.2	3.8	43.0	-18 59	8.4	10.1	10.0	NOV
DEC	21.2	4.6	21.5	28.4 62	11.2 61	43 65	36.7	2.9	37.0	-25 68	-2.8	11.3	-3.5	DEC

(con.)

Table 32. (Con.)

MEAN DAILY TEMPERATURE — MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 247978 SUMMIT — 1949-1978

10-DAY AND MONTHLY PERIOD MEANS | 10-DAY AND MONTHLY EXTREMES

PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD BEGI
JAN 1	13.8	8.5	15.0	27.8 61	-5.4 73	40 54	27.6	6.4	25.0	-34 59	-6.4	14.7	-1.0	JAN
JAN 11	14.4	11.2	16.0	29.9 61	-8.9 50	41 61	28.4	8.9	29.0	-29 54	-5.4	15.1	-1.0	JAN
JAN 21	13.6	12.3	17.0	29.9 53	-12.6 69	43 68	29.0	10.0	31.0	-29 50	-6.1	16.0	-1.0	JAN
FEB 1	21.4	8.1	20.0	34.1 54	-4.8 75	47 62	32.7	6.4	33.0	-18 75	6.3	12.1	4.0	FEB
FEB 11	21.1	6.4	21.5	33.9 77	3.6 49	43 58	32.5	5.3	33.5	-23 56	3.6	13.1	5.0	FEB
FEB 21	21.4	10.2	23.0	35.8 68	-13.9 62	43 58	31.3	9.0	32.5	-24 62	8.7	14.1	9.5	FEB
MAR 1	19.8	7.9	20.0	36.3 68	-6.9 51	46 72	33.4	5.7	33.0	-29 60	1.4	13.8	1.5	MAR
MAR 11	23.9	6.8	24.0	40.1 72	8.5 67	46 60	35.2	6.0	36.0	-19 65	9.7	12.8	10.0	MAR
MAR 21	27.5	7.9	28.5	41.3 78	8.0 65	50 78	38.3	5.6	39.5	-16 65	13.8	13.3	18.0	MAR
APR 1	32.2	5.1	32.0	41.1 69	15.7 75	52 60	41.8	5.2	42.0	-10 54	19.9	9.4	20.0	APR
APR 11	33.3	5.1	32.5	44.0 62	20.8 53	53 62	42.1	4.9	42.0	5 51	22.9	7.9	24.0	APR
APR 21	34.9	5.5	34.5	45.6 77	23.4 54	53 68	43.7	5.4	44.0	6 51	24.7	7.2	26.0	APR
MAY 1	39.4	4.0	39.5	47.2 58	31.4 56	54 58	46.7	3.8	47.0	15 54	31.1	6.2	32.0	MAY
MAY 11	43.2	3.5	42.5	48.4 56	33.4 66	60 73	51.4	4.6	50.5	24 67	34.1	5.0	34.0	MAY
MAY 21	45.4	3.8	44.0	55.3 58	39.3 78	61 58	53.1	4.0	53.0	30 75	37.2	4.7	37.0	MAY
JUN 1	48.9	4.4	47.0	56.8 72	40.5 51	66 77	56.8	4.8	56.0	29 66	40.6	4.8	41.0	JUN
JUN 11	50.5	3.6	49.0	61.6 74	46.1 57	67 61	58.3	4.2	58.0	34 76	42.8	4.9	42.0	JUN
JUN 21	51.9	4.0	51.0	59.9 74	42.6 51	70 70	60.2	5.1	60.5	33 71	42.9	5.2	42.5	JUN
JUL 1	54.9	3.7	55.0	62.7 70	47.0 71	67 78	61.2	3.3	60.0	39 55	47.4	4.2	47.0	JUL
JUL 11	57.2	3.5	57.0	66.1 55	50.3 62	71 73	63.8	4.1	63.0	40 74	49.3	4.9	49.0	JUL
JUL 21	57.8	2.6	57.0	63.6 60	53.6 54	74 60	64.8	3.6	65.0	44 75	50.2	3.0	50.0	JUL
AUG 1	57.5	3.2	58.0	64.2 71	50.2 75	73 61	64.9	4.3	65.0	38 77	49.6	4.0	49.0	AUG
AUG 11	56.2	3.5	56.0	62.6 61	49.9 74	70 61	62.9	3.5	63.0	40 66	49.2	4.4	49.0	AUG
AUG 21	53.1	3.8	52.0	61.7 61	47.3 64	73 69	61.4	4.8	60.0	36 65	44.3	4.6	45.0	AUG
SEP 1	50.3	5.0	50.0	59.9 67	38.0 64	71 50	59.6	5.8	60.0	28 64	40.8	5.9	41.5	SEP
SEP 11	46.1	4.9	46.0	53.9 60	32.8 65	67 53	56.8	5.6	58.5	16 70	35.1	7.2	35.0	SEP
SEP 21	44.7	6.5	44.0	55.6 63	33.0 72	65 67	54.1	6.7	55.0	18 65	34.6	8.2	34.5	SEP
OCT 1	41.6	5.5	42.0	48.9 71	31.2 59	60 60	53.2	4.9	55.0	15 70	29.6	8.0	32.0	OCT
OCT 11	39.0	5.5	39.0	46.8 55	25.8 69	62 61	48.0	6.4	47.0	14 49	28.5	6.0	30.0	OCT
OCT 21	34.8	5.5	34.0	44.7 65	24.6 61	55 66	45.1	4.9	46.0	6 71	22.9	8.3	24.0	OCT
NOV 1	30.4	7.0	30.0	40.8 49	4.8 73	54 75	41.1	5.5	41.0	-7 73	17.4	11.6	18.0	NOV
NOV 11	24.5	8.3	26.0	35.9 49	-2.2 55	45 76	35.7	5.7	36.0	-24 55	11.3	13.1	13.0	NOV
NOV 21	22.9	6.0	23.5	35.4 49	10.6 52	45 50	34.2	5.6	34.0	-11 70	7.9	10.7	8.5	NOV
DEC 1	20.5	7.8	21.0	32.6 65	-4.6 72	43 50	33.6	4.9	34.0	-32 56	4.1	14.5	10.0	DEC
DEC 11	18.9	9.4	20.5	32.1 76	-1.9 64	42 60	30.9	6.2	31.0	-30 64	4.8	14.4	8.0	DEC
DEC 21	18.8	8.8	20.5	30.9 50	-8.7 68	40 50	30.9	5.8	32.0	-38 68	3.9	14.1	8.0	DEC
MONTH														MTH
JAN	13.9	7.6	14.0	26.3 58	-6.0 50	43 68	34.7	4.9	35.0	-34 59	-15.1	12.5	-1.0	JAN
FEB	21.3	4.9	21.5	29.8 77	12.5 49	47 62	36.7	4.3	37.0	-24 62	-3.6	11.5	-1.0	FEB
MAR	23.8	5.3	23.5	33.5 68	13.5 65	50 78	40.3	3.9	40.0	-29 60	-2.5	13.2	-1.0	MAR
APR	33.5	3.4	33.0	40.3 49	27.1 75	53 68	46.8	3.8	47.0	-10 54	16.4	8.7	17.5	APR
MAY	42.7	2.4	42.0	50.1 58	39.5 50	61 58	54.5	3.8	53.5	15 54	29.2	5.4	30.0	MAY
JUN	50.4	2.9	50.0	57.1 61	44.3 51	70 70	62.5	3.2	62.0	29 66	38.1	4.2	38.5	JUN
JUL	56.7	2.1	56.0	61.8 60	52.6 62	74 60	66.0	3.3	65.0	39 55	45.5	3.4	46.0	JUL
AUG	55.5	2.9	55.0	62.2 61	50.3 75	73 69	66.8	3.3	67.0	36 65	43.6	4.4	44.0	AUG
SEP	47.0	4.1	46.0	54.5 67	36.4 65	71 50	61.6	4.5	61.0	16 70	30.1	6.7	30.0	SEP
OCT	38.5	3.6	38.0	46.9 53	32.1 69	62 61	54.5	3.7	55.0	6 71	20.9	7.6	22.0	OCT
NOV	26.0	4.9	25.0	37.4 49	12.8 55	54 75	42.4	4.5	41.0	-24 55	3.4	11.9	3.0	NOV
DEC	19.4	5.1	20.0	26.7 57	10.2 68	43 50	36.0	4.3	36.0	-38 68	-8.5	14.1	-1.0	DEC

Table 33.--Afternoon dry bulb temperature (°F) and relative humidity (percent) statistics at fire-weather stations in or near Glacier National Park; at 1600 m.s.t., based on years 1951-70 except as noted. Also, 1300 m.s.t. data observed during 1974-83 (see discussion in text). Letter M following year of highest or lowest average denotes average computed with incomplete data; based on at least six daily values per 10-day period

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS: MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES: HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	19	74.0	6.5	74.0	86.2 68	61.5 55	93 68	86.2	4.8	88.0	44 55	59.9	7.6	59.0	JUL 1
JUL 11	20	79.1	5.8	77.5	90.0 60	70.5 68	98 60	88.8	4.5	88.5	58 70	67.4	8.1	66.0	JUL 11
JUL 21	20	80.4	4.8	81.0	87.9 60	72.0 70	96 59	89.3	4.0	90.0	54 54	65.6	8.8	62.0	JUL 21
AUG 1	19	78.4	5.7	80.0	87.9 61	67.0 62	99 61	88.4	6.0	89.0	54 69	63.6	7.1	62.0	AUG 1
AUG 11	20	78.5	7.4	79.0	93.7 67	61.6 68	98 67	87.6	5.7	89.5	52 68	65.8	10.6	63.5	AUG 11
AUG 21	20	72.1	7.8	71.5	86.1 70	60.9 51	99 69	86.3	7.2	86.5	48 51	57.6	7.4	55.5	AUG 21
SEP 1	18	70.3	8.3	71.0	84.5 67	55.0 64	97 67	82.9	7.8	84.0	40 62	54.2	8.5	54.0	SEP 1
SEP 11	13	66.1	7.5	63.0	76.4 56	54.5 70	91 58	80.5	7.4	84.0	39 70	49.8	8.1	47.0	SEP 11
SEP 21	7	61.5	8.5	59.0	77.8 67	51.6 59	86 67	75.3	7.3	75.0	40 68	47.4	6.2	46.0	SEP 21
MONTH															MONTH
JUL	20	77.9	3.3	77.0	86.8 60	72.8 63 M	98 60	91.4	3.6	91.5	44 55	57.2	5.9	57.0	JUL
AUG	20	76.2	5.4	74.5	86.8 67	68.5 64	99 69	91.8	4.0	91.5	48 51	54.8	4.7	54.5	AUG
SEP	12	66.8	7.1	68.0	79.3 67	57.1 70 M	97 67	84.7	6.8	84.0	39 70	46.3	5.8	45.0	SEP

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS: MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES: HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	19	40.3	12.2	39.0	63.5 55	20.6 67	94 56	68.0	20.1	77.0	12 60	21.9	7.0	22.0	JUL 1
JUL 11	20	34.8	6.7	35.5	45.7 70	22.9 67	94 70	59.3	15.5	57.0	15 67	20.1	3.8	20.5	JUL 11
JUL 21	20	29.9	8.4	28.0	50.5 55	19.2 69	94 65	56.9	20.8	51.0	9 68	16.3	5.0	15.5	JUL 21
AUG 1	19	34.7	10.7	33.0	53.3 62	19.7 61	100 60	67.1	21.0	66.0	7 65	18.5	6.9	18.0	AUG 1
AUG 11	20	32.0	11.5	30.0	64.1 68	17.5 67	94 51	57.8	21.9	55.0	8 66	16.6	6.3	14.5	AUG 11
AUG 21	20	39.2	13.6	39.0	63.5 51	17.6 69	93 62	70.5	19.4	76.5	9 66	19.3	8.8	16.5	AUG 21
SEP 1	18	38.2	12.0	34.0	59.1 64	22.8 66	94 63	68.8	22.1	75.5	7 65	20.2	8.8	19.0	SEP 1
SEP 11	13	43.3	13.4	44.0	62.3 59	25.1 60	93 54	71.8	18.2	74.0	5 60	23.1	8.2	22.0	SEP 11
SEP 21	7	51.4	15.7	56.0	67.7 59	18.6 67	100 70	84.3	23.4	93.0	9 67	28.4	11.7	29.0	SEP 21
MONTH															MONTH
JUL	20	34.8	6.7	35.5	49.1 55	21.5 67	94 70	78.3	15.3	83.5	9 68	14.9	3.3	15.0	JUL
AUG	20	35.5	8.4	35.0	47.6 54	21.6 69	100 60	82.6	11.9	84.5	7 65	13.0	3.5	12.5	AUG
SEP	12	43.4	11.7	40.0	60.4 59	24.1 67	100 70	84.5	14.9	92.0	5 60	21.3	8.7	19.0	SEP

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240210 POLEBRIDGE RS 1974-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS: MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES: HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUN 21	7	70.2	4.7	69.0	76.4 77	63.4 80	85 79	80.9	3.9	82.0	47 76	60.3	7.7	61.0	JUN 21
JUL 1	9	70.2	6.5	68.0	85.8 75	64.1 82	92 75	80.9	5.5	80.0	46 81	57.0	9.0	53.0	JUL 1
JUL 11	10	71.4	4.9	70.5	78.6 74	64.1 80 M	92 79	84.8	5.1	85.0	50 82	56.9	4.6	56.5	JUL 11
JUL 21	10	75.3	4.8	75.0	83.1 74	67.2 81	94 75	85.0	5.8	84.5	52 77	61.7	6.8	62.5	JUL 21
AUG 1	9	74.2	4.6	74.0	80.8 79	67.3 80	90 74	83.0	4.6	84.0	53 76	62.6	6.7	61.0	AUG 1
AUG 11	10	70.3	5.9	69.5	81.5 81	61.6 78	90 81	80.2	5.6	79.0	50 78	57.9	7.1	57.0	AUG 11
AUG 21	10	67.7	6.0	68.5	77.6 81	59.3 75	93 81	77.8	6.5	76.5	51 75	55.2	3.8	55.0	AUG 21
MONTH															MONTH
JUL	10	72.6	4.9	71.0	81.0 74 M	66.1 83 M	94 75	87.0	5.1	88.0	46 81	53.0	3.4	53.5	JUL
AUG	9	70.3	4.3	69.0	78.9 81	64.7 80 M	93 81	85.1	4.9	85.0	50 78	52.9	3.0	52.0	AUG

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240210 POLEBRIDGE RS 1974-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS: MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES: HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUN 21	7	46.9	9.8	52.0	56.5 83	32.1 79	90 83	76.6	15.4	82.0	7 79	26.7	10.4	26.0	JUN 21
JUL 1	9	52.9	12.2	48.0	72.9 78	38.7 80	100 82	80.4	16.7	87.0	16 79	31.9	11.1	29.0	JUL 1
JUL 11	10	50.4	8.3	48.0	65.3 80 M	37.5 74	100 80	83.2	14.2	87.5	23 74	30.0	5.8	29.0	JUL 11
JUL 21	10	46.8	10.7	46.5	60.7 83 M	31.6 74	95 76	76.4	16.5	80.5	8 78	26.6	10.4	25.5	JUL 21
AUG 1	9	46.3	11.0	43.0	63.9 82 M	33.2 79	95 82	72.7	17.0	71.0	17 75	25.4	6.1	25.0	AUG 1
AUG 11	10	52.8	9.7	52.5	65.5 76	36.3 81	100 80	83.2	14.5	85.0	20 81	32.7	10.2	35.0	AUG 11
AUG 21	10	54.8	11.8	54.0	72.0 77	35.1 81	100 77	84.8	9.8	88.0	17 81	36.8	10.5	39.5	AUG 21
MONTH															MONTH
JUL	10	49.5	7.5	51.0	60.6 83 M	34.4 74 M	100 82	90.3	11.3	92.0	8 78	23.5	8.6	24.0	JUL
AUG	9	51.8	8.6	54.0	62.5 76	36.4 81	100 80	93.2	4.7	94.0	17 81	22.8	5.5	22.0	AUG

(con.)

Table 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240217 HUNGRY HORSE RS (INCLUDES CORAM RS, 1951-1957) 1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD BEGI
MAY 1	9	59.4	8.3	56.0	72.2 66 M	50.6 64	85 66	70.3	9.0	69.0	36 67	48.4	8.5	46.0	MAY
MAY 11	11	61.7	5.4	62.0	71.4 58	52.7 66	83 58	75.4	4.1	75.0	38 67	44.4	7.2	42.0	MAY
MAY 21	14	62.7	8.1	62.0	79.8 58	51.9 59 M	86 66	74.8	8.3	76.0	38 64	49.5	7.4	50.0	MAY
JUN 1	19	66.7	5.7	67.0	76.1 70	58.0 54 M	87 70	77.6	6.9	79.0	44 62	53.8	6.8	53.0	JUN
JUN 11	20	67.7	6.0	66.5	81.3 61	55.8 54 M	93 61	80.1	6.4	80.5	43 65	53.3	6.5	51.5	JUN
JUN 21	19	69.0	6.1	68.0	80.8 61	56.5 69	89 70	80.3	6.3	81.0	45 66	54.4	6.3	54.0	JUN
JUL 1	20	74.7	7.0	75.0	84.6 68	58.0 55	92 68	86.3	5.0	86.5	42 55	60.8	9.2	60.0	JUL
JUL 11	20	80.1	5.7	79.0	94.1 60	71.3 52	101 60	89.6	4.3	89.0	55 70	67.8	9.3	64.5	JUL
JUL 21	20	80.9	4.7	81.5	88.5 60	71.0 70	96 60	89.8	3.5	90.5	51 54	67.1	8.4	65.0	JUL
AUG 1	20	79.2	5.1	80.0	88.3 61	70.0 62	103 61	89.2	4.8	90.0	51 56	63.9	7.2	64.0	AUG
AUG 11	20	79.0	6.9	79.0	94.5 67	63.9 68	97 67	88.3	4.8	87.5	50 66	65.9	11.2	65.0	AUG
AUG 21	20	72.1	7.7	71.0	83.8 67	59.9 60	100 69	86.1	6.4	85.5	47 51	58.8	8.7	57.5	AUG
SEP 1	20	69.8	7.1	69.0	82.7 67	58.4 64	97 67	81.7	7.5	82.0	43 62	55.0	7.6	54.5	SEP
SEP 11	20	64.8	7.4	64.0	75.0 56	45.0 65	92 58	77.8	8.8	80.0	36 65	49.0	7.2	50.0	SEP
SEP 21	19	61.9	9.7	60.0	77.3 57	47.5 51 M	87 67	72.1	9.3	72.0	39 65	50.1	9.3	49.0	SEP
OCT 1	13	58.4	6.4	58.0	68.0 52	47.7 69	77 70	70.4	6.4	72.0	32 70	48.1	8.2	50.0	OCT
OCT 11	11	52.2	5.9	52.0	62.1 53 M	44.6 66	70 53	60.6	5.2	60.0	35 66	44.3	5.7	45.0	OCT
OCT 21	11	45.1	6.1	45.0	54.4 53 M	36.9 57 M	63 69	54.6	6.8	57.0	21 57	36.1	6.9	36.0	OCT
MONTH															MO
MAY	9	62.5	5.2	62.0	74.0 58	57.1 64	86 66	80.0	4.8	80.0	36 67	40.7	3.3	39.0	
JUN	18	68.0	3.7	67.0	78.7 61	62.5 54 M	93 61	85.2	3.4	85.0	43 65	49.2	4.9	48.0	
JUL	20	78.7	3.5	78.0	88.7 60	71.9 55	101 60	92.0	2.9	91.5	42 55	57.9	7.4	58.5	
AUG	20	76.6	5.0	75.0	87.0 67	68.9 64	103 61	91.8	4.4	91.0	47 51	55.1	6.1	53.5	
SEP	20	65.8	6.1	65.5	77.4 67	52.9 65	97 67	83.4	6.6	84.0	36 65	45.9	6.3	43.0	
OCT	10	52.2	5.1	50.5	60.1 53 M	45.7 69 M	77 70	70.5	5.4	71.5	21 57	36.9	4.8	35.5	

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240217 HUNGRY HORSE RS (INCLUDES CORAM RS, 1951-1957) 1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PR BE(
MAY 1	9	40.9	12.7	38.0	67.2 64	26.9 66 M	91 67	69.3	17.7	70.0	11 66	22.2	10.4	21.0	MA
MAY 11	11	40.5	7.2	41.0	53.1 57 M	27.5 63	92 65	77.5	14.3	84.0	15 70	19.7	5.4	19.0	MA
MAY 21	14	44.2	10.6	41.5	63.1 64	26.9 58	93 68	75.9	13.3	77.5	10 66	22.4	8.0	26.0	MA
JUN 1	19	45.6	12.1	43.0	66.0 66	25.2 65	99 69	73.1	20.9	80.0	9 65	27.0	7.5	26.0	JU
JUN 11	20	44.5	10.7	42.5	64.1 64	30.5 61	93 65	70.4	19.8	78.0	13 61	25.6	6.6	25.5	JU
JUN 21	19	43.1	12.1	41.0	66.7 69	20.1 61	100 63	78.1	21.6	86.0	10 56	24.2	7.1	23.0	JU
JUL 1	20	38.4	12.3	36.0	69.4 55	21.5 68	95 58	65.8	23.8	69.0	11 61	22.4	7.3	21.5	JU
JUL 11	20	31.8	7.7	31.0	47.1 52	16.7 60	94 70	54.8	19.7	53.0	10 60	18.9	4.3	20.0	JU
JUL 21	20	28.0	9.4	26.5	50.6 70	17.5 60	94 70	54.0	22.5	45.0	6 67	15.5	5.6	15.0	JU
AUG 1	20	31.7	10.6	27.5	48.1 62	17.9 59	94 70	64.9	22.3	67.5	7 61	16.2	5.6	16.0	AU
AUG 11	20	28.7	10.4	26.0	55.7 68	10.4 67	94 68	54.4	24.5	46.0	6 67	15.7	5.7	15.5	AU
AUG 21	20	39.0	14.5	34.5	63.9 65	16.0 67	100 54	70.4	23.0	77.0	8 69	20.1	8.1	19.0	AU
SEP 1	20	39.0	10.5	38.5	58.0 70	21.7 67	100 70	72.9	20.8	77.0	10 67	20.1	6.6	19.5	SE
SEP 11	20	42.9	12.3	39.0	72.0 65	25.2 53	93 65	75.2	16.3	79.0	9 58	24.7	9.3	24.0	SE
SEP 21	19	45.9	12.8	50.0	64.3 61 M	19.9 67	100 56	72.6	20.5	85.0	10 67	28.8	9.8	26.0	SE
OCT 1	13	49.0	13.8	46.0	66.2 69	27.6 52	100 70	77.2	21.3	87.0	12 70	26.7	7.8	26.0	OC
OCT 11	11	52.6	12.8	55.0	75.7 64	34.4 52	93 66	74.7	17.6	79.0	17 69	30.9	9.4	30.0	OC
OCT 21	11	65.1	12.6	71.0	78.2 70	40.7 52	100 56	87.5	10.0	92.0	24 53	43.0	9.8	45.0	OC
MONTH															M TH
MAY	9	40.8	7.6	40.0	57.4 64	29.4 58	93 68	88.0	5.0	89.0	10 66	15.8	6.8	15.0	AY
JUN	18	44.5	6.0	46.0	51.8 57 M	27.8 61	100 63	89.9	11.0	93.0	9 65	19.3	5.1	21.0	UN
JUL	20	32.5	7.5	32.0	51.6 55	18.9 60	95 58	75.8	17.6	81.5	6 67	14.4	4.9	13.0	UL
AUG	20	33.3	8.7	33.5	44.7 65	15.7 67	100 54	78.9	18.4	82.5	6 67	12.8	4.3	12.0	UG
SEP	20	42.4	9.0	42.5	55.7 65	24.7 67	100 70	84.9	14.6	90.0	9 58	18.5	5.9	18.0	EP
OCT	10	55.3	11.4	57.0	71.0 64 M	34.5 52	100 70	90.1	11.1	92.0	12 70	24.5	8.0	23.5	CT

Table 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240217 HUNGRY HORSE RS

1974-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG.YR	LOWEST AVG.YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
MAY 1	8	56.2	4.7	54.5	64.3 76	51.5 81 M	81 80	67.1	8.4	66.0	36 78	45.0	4.6	45.5	MAY 1
MAY 11	9	59.1	4.5	58.0	66.8 80	53.5 78	76 76	70.8	3.9	72.0	44 83	48.8	5.7	46.0	MAY 11
MAY 21	9	60.5	7.2	57.0	75.3 83	51.0 78	84 83	75.0	4.2	73.0	31 78	46.9	10.2	46.0	MAY 21
JUN 1	10	63.2	4.9	62.0	70.1 78	57.6 80	81 77	74.3	5.3	75.0	40 80	49.9	7.4	48.0	JUN 1
JUN 11	10	66.7	7.9	63.5	81.2 74	57.1 81	88 74	77.4	7.8	77.5	46 76	55.4	7.4	53.0	JUN 11
JUN 21	10	66.6	5.3	68.0	75.3 77	61.2 76	86 76	79.5	4.8	80.5	44 76	56.6	8.7	56.0	JUN 21
JUL 1	10	70.0	3.9	69.0	79.3 75	66.2 82	85 75	79.6	3.1	79.0	51 81	57.2	4.3	56.5	JUL 1
JUL 11	10	70.6	4.5	70.5	77.2 79	63.4 83	90 79	81.9	5.1	83.0	50 82	55.1	3.5	55.5	JUL 11
JUL 21	10	76.8	4.7	78.0	82.5 74	69.3 83 M	90 75	84.4	4.6	85.0	58 81	66.8	7.5	66.0	JUL 21
AUG 1	9	74.9	4.9	72.0	82.1 79	69.5 80	88 78	83.4	3.9	85.0	55 74	64.0	8.2	59.0	AUG 1
AUG 11	10	71.2	5.9	70.5	82.0 81	62.5 78	87 81	80.8	3.3	79.5	51 80	60.3	8.0	57.5	AUG 11
AUG 21	10	68.7	6.6	70.5	78.5 81	58.7 75	92 81	78.9	6.5	79.5	47 77	55.9	5.1	56.0	AUG 21
SEP 1	10	66.1	2.8	66.0	70.7 82	60.8 83	82 78	76.9	3.8	78.5	47 82	52.2	4.1	51.5	SEP 1
SEP 11	10	63.0	5.8	61.5	73.1 81	53.0 78	82 79	71.5	6.6	70.5	44 78	52.3	5.9	51.5	SEP 11
SEP 21	10	60.1	6.3	62.0	68.7 79	48.4 77	78 79	68.2	7.3	70.5	43 82	50.3	6.9	48.5	SEP 21
MONTH															MONTH
MAY	8	58.3	3.0	58.5	61.0 81 M	52.4 78	84 83	75.4	3.2	75.0	31 78	42.0	4.9	44.0	MAY
JUN	10	66.2	4.1	65.5	71.8 77	60.7 81	88 74	81.6	4.2	81.0	40 80	48.0	5.6	46.5	JUN
JUL	10	72.6	3.3	72.0	77.3 75	66.0 83 M	90 79	85.3	3.7	85.0	50 82	53.8	2.8	54.0	JUL
AUG	9	71.3	4.8	68.0	80.1 81	66.1 75	92 81	84.7	4.3	85.0	47 77	53.4	3.6	54.0	AUG
SEP	10	63.0	3.1	62.5	69.1 79	58.4 77	82 79	77.2	4.0	78.5	43 82	46.9	4.0	46.0	SEP

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240217 HUNGRY HORSE RS

1974-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG.YR	LOWEST AVG.YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
MAY 1	8	55.3	6.9	54.0	66.2 79	44.0 76	93 78	84.6	5.8	86.0	15 80	27.8	10.2	28.0	MAY 1
MAY 11	9	46.4	6.9	43.0	59.8 78	40.2 83	94 78	81.3	12.8	82.0	13 79	21.2	8.7	17.0	MAY 11
MAY 21	9	50.9	12.2	53.0	65.1 80	28.9 83	100 82	78.7	19.9	84.0	15 83	28.3	8.9	34.0	MAY 21
JUN 1	10	48.6	10.4	47.0	70.7 81	32.8 78	94 76	78.8	12.7	83.5	17 76	25.3	10.0	22.0	JUN 1
JUN 11	10	49.2	10.3	48.0	63.1 81	31.4 77	94 83	79.8	16.1	84.0	13 77	27.3	9.3	25.5	JUN 11
JUN 21	10	45.8	12.3	47.5	60.4 80	24.8 77	95 83	72.9	19.3	71.0	11 77	26.8	9.9	26.5	JUN 21
JUL 1	10	46.9	9.1	42.5	64.6 78	36.4 77	89 78	74.7	8.9	74.5	11 76	26.2	11.7	26.5	JUL 1
JUL 11	10	49.4	10.9	49.5	67.7 83	31.0 79	95 83	82.5	11.8	88.0	20 79	30.3	7.9	30.0	JUL 11
JUL 21	10	39.2	10.6	39.0	57.7 83 M	22.0 74	89 83	64.2	22.1	63.5	9 80	23.1	10.7	19.5	JUL 21
AUG 1	9	39.2	11.7	41.0	56.3 76	21.9 79	89 77	61.8	23.0	64.0	14 79	24.6	7.8	24.0	AUG 1
AUG 11	10	47.0	9.6	47.0	60.4 78	33.4 81	94 78	74.2	19.2	82.5	19 79	27.0	5.0	26.0	AUG 11
AUG 21	10	48.7	10.9	47.5	66.8 75	31.6 81	94 78	78.2	15.5	82.0	16 81	29.3	6.7	29.0	AUG 21
SEP 1	10	48.6	7.4	47.0	61.5 83	37.4 74	88 83	80.7	5.0	81.5	13 74	27.3	7.7	26.5	SEP 1
SEP 11	10	48.1	10.0	47.5	63.8 80	34.1 79	94 77	69.1	17.4	73.5	19 77	32.4	9.4	30.0	SEP 11
SEP 21	10	51.4	12.3	48.5	70.0 77	31.3 79	100 77	74.1	18.1	77.0	16 78	31.2	12.1	28.5	SEP 21
MONTH															MONTH
MAY	8	52.0	5.3	52.0	58.5 78	43.1 76	100 82	90.4	8.4	91.0	13 79	19.1	6.8	16.5	MAY
JUN	10	47.9	8.7	50.0	60.5 81	32.6 77	95 83	87.1	8.2	87.0	11 77	20.6	5.1	21.5	JUN
JUL	10	45.0	8.3	44.0	60.8 83 M	33.4 79	95 83	86.0	8.3	88.0	9 80	21.1	10.4	17.5	JUL
AUG	9	45.1	7.8	48.0	52.4 76	31.7 81	94 78	85.1	9.3	88.0	14 79	21.7	5.9	24.0	AUG
SEP	10	49.5	7.4	49.0	58.1 77	37.6 79	100 77	86.6	6.6	86.5	13 74	21.5	5.2	21.0	SEP

(con.)

Table 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240301 BELLY RIVER RS

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUN 21	13	60.2	5.1	60.0	72.2 61	52.3 69
JUL 1	17	67.2	5.8	67.0	75.3 68	54.0 55
JUL 11	20	71.4	5.4	70.5	83.3 60	62.7 52
JUL 21	20	71.5	4.5	71.0	81.2 60	63.0 70
AUG 1	19	70.8	4.5	71.0	78.7 61	62.0 56
AUG 11	20	70.3	6.8	71.0	85.5 67	54.5 68
AUG 21	20	64.9	7.1	63.5	76.1 67	52.5 51
SEP 1	17	62.2	8.8	64.0	76.6 67	44.6 64
SEP 11	10	59.7	5.6	59.5	66.7 67	51.0 57
MONTH						
JUL	20	70.3	3.3	69.0	79.4 60	66.0 55
AUG	20	68.6	4.7	66.0	78.2 67	62.5 51

10-DAY AND MONTHLY EXTREME DAILY VALUES

HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD BEGI
80 61	71.8	5.2	73.0	39 63	47.0	5.9	46.0	JUN
84 70	78.1	4.6	78.0	41 55	54.2	7.0	51.0	JUL
92 60	80.9	4.8	80.0	47 58	59.4	7.4	58.0	JUL
92 60	81.3	4.9	81.0	47 54	56.7	5.6	56.5	JUL
95 61	81.8	4.7	81.0	48 69	56.2	6.3	54.0	AUG
90 67	79.8	6.1	80.0	42 66	56.9	8.6	57.0	AUG
93 69	79.0	6.4	78.0	36 52	50.5	8.2	50.0	AUG
90 67	76.4	7.1	77.0	32 64	46.0	10.1	47.0	SEP
85 58	75.7	4.9	75.0	29 68	41.7	7.4	43.0	SEP
								MO
92 60	83.5	3.9	83.5	41 55	51.6	5.6	50.5	
95 61	84.6	4.4	83.5	36 52	47.5	6.3	47.5	

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240301 BELLY RIVER RS

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUN 21	13	53.7	12.4	53.0	77.0 69	29.3 61
JUL 1	17	48.0	10.8	46.0	68.6 55	33.5 67
JUL 11	20	42.5	8.3	41.5	55.8 58	28.8 60
JUL 21	20	41.1	10.2	39.5	61.4 61	25.6 60
AUG 1	19	42.6	11.0	41.0	63.4 56	23.8 59
AUG 11	20	40.6	11.6	42.5	69.3 68	19.0 67
AUG 21	20	46.0	12.9	47.0	73.5 51	24.6 69
SEP 1	17	49.3	13.9	47.0	76.1 64	26.5 67
SEP 11	10	49.7	9.0	47.5	63.4 68	36.1 67
MONTH						
JUL	20	43.4	7.4	43.5	57.7 55	29.3 60
AUG	20	43.6	9.0	43.0	55.5 51	25.5 67

10-DAY AND MONTHLY EXTREME DAILY VALUES

HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PR BE
100 68	86.2	15.3	93.0	11 61	29.8	12.3	27.0	JU
93 56	75.2	12.8	81.0	21 60	29.8	7.2	29.0	JU
94 66	67.1	18.0	64.5	15 60	26.5	6.1	26.0	JU
94 55	72.1	14.0	74.0	10 60	24.1	8.0	22.0	JU
94 65	75.2	19.2	82.0	8 61	22.7	8.0	22.0	AU
93 68	69.2	19.7	73.0	11 67	22.8	9.0	22.0	AU
100 51	74.4	17.8	80.0	13 69	23.7	6.4	23.5	AU
100 65	82.6	18.5	92.0	14 67	24.8	7.2	23.0	SE
100 69	88.3	9.0	89.5	17 69	26.2	6.3	27.5	SE
								M H
94 66	83.5	8.8	85.0	10 60	21.0	4.6	22.0	
100 51	84.5	14.9	92.5	8 61	18.4	5.1	19.0	

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240301 BELLY RIVER RS

1974-1983

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	7	65.5	5.6	63.0	76.3 75	60.2 82
JUL 11	9	65.6	4.1	63.0	70.5 75	60.6 80
JUL 21	9	70.8	4.1	71.0	76.7 80	63.7 81
AUG 1	9	69.1	4.2	67.0	74.8 79	63.5 77
AUG 11	10	66.4	6.4	65.0	80.2 81	57.7 78
AUG 21	10	64.2	7.5	64.0	79.0 81 M	54.9 80
MONTH						
JUL	9	67.4	2.9	67.0	72.8 75	63.7 83 M
AUG	9	66.1	5.2	64.0	77.4 81 M	61.5 75

10-DAY AND MONTHLY EXTREME DAILY VALUES

HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	P BE
86 75	76.0	6.5	76.0	48 82	53.3	3.5	54.0	JU
84 75	77.0	4.5	76.0	46 80	50.6	2.8	51.0	JU
85 75	79.4	3.5	80.0	50 75	58.7	6.2	60.0	JU
83 78	78.8	4.0	80.0	46 78	54.7	8.2	52.0	AU
85 81	76.4	5.0	75.0	44 78	53.3	7.9	52.5	AU
88 81	75.9	6.5	76.0	47 80	52.6	7.5	49.5	AU
								TH
86 75	80.7	2.9	80.0	46 80	49.7	2.1	50.0	JUL
88 81	81.1	4.2	81.0	44 78	49.6	7.1	47.0	AUG

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240301 BELLY RIVER RS

1974-1983

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	7	50.4	10.6	50.0	69.3 74	38.0 76
JUL 11	9	53.5	6.6	49.0	63.6 83	46.9 76
JUL 21	9	46.9	7.5	49.0	58.0 81	35.2 80
AUG 1	9	48.1	12.0	46.0	70.5 76	33.7 79
AUG 11	10	51.6	11.2	52.5	65.0 75	33.3 81
AUG 21	10	53.6	12.3	55.0	67.6 75	27.8 81 M
MONTH						
JUL	9	50.6	3.2	50.0	56.2 83 M	46.2 76
AUG	9	51.9	9.1	55.0	60.0 75	33.2 81 M

10-DAY AND MONTHLY EXTREME DAILY VALUES

HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	D.
100 75	79.9	14.4	75.0	13 76	30.1	11.2	27.0	
100 83	88.4	11.2	89.0	20 74	31.4	8.2	33.0	
95 78	77.9	20.7	94.0	25 80	29.7	5.2	28.0	
100 77	77.2	20.6	82.0	20 79	31.6	9.4	31.0	
100 74	78.7	16.1	78.0	19 79	30.8	7.9	34.0	
100 78	79.9	19.0	84.5	18 81	30.5	7.5	29.5	
								MTH
100 83	95.7	4.6	95.0	13 76	24.1	4.8	26.0	JUL
100 78	89.9	16.5	94.0	18 81	26.4	6.6	26.0	AUG

ble 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240303 SAINT MARY RS

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUN 11	8	63.8	7.1	60.0	76.0 61	56.1 57
JUN 21	13	65.0	5.8	64.0	76.3 61	56.2 52
JUL 1	15	68.2	5.7	70.0	76.6 61	55.4 55
JUL 11	19	74.7	5.6	74.0	85.6 60	62.9 52
JUL 21	18	75.4	4.7	74.0	83.6 60	68.8 55
AUG 1	19	73.4	4.9	73.0	81.1 61	62.8 56 M
AUG 11	19	73.8	5.7	74.0	87.1 67	65.1 66
AUG 21	19	67.2	7.5	66.0	79.7 70	55.0 51
SEP 1	16	61.3	6.8	62.0	70.4 55	47.0 64
SEP 11	8	58.7	5.0	57.0	67.7 56	53.4 57
MONTH						
JUL	19	73.3	4.4	72.0	81.5 60	67.0 69 M
AUG	19	71.4	4.7	69.0	80.3 67	64.9 51

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUN 11	85 61	75.6	7.3	74.5	43 56	51.5	7.1	48.5	JUN 11
JUN 21	85 62	75.4	6.1	75.0	42 63	51.8	6.2	51.0	JUN 21
JUL 1	90 54	81.5	5.7	83.0	41 55	55.1	6.5	55.0	JUL 1
JUL 11	96 60	84.3	5.9	84.0	48 58	62.2	8.1	62.0	JUL 11
JUL 21	94 59	85.2	4.6	85.0	50 54	60.6	8.0	60.5	JUL 21
AUG 1	97 61	85.0	5.5	85.0	47 56	56.8	6.4	56.0	AUG 1
AUG 11	93 67	83.7	4.6	84.0	44 66	59.1	8.5	60.0	AUG 11
AUG 21	99 69	81.7	7.2	82.0	38 52	52.7	8.9	53.0	AUG 21
SEP 1	86 69	76.0	5.9	75.0	31 62	44.3	8.5	44.0	SEP 1
SEP 11	84 59	75.6	5.1	73.5	32 57	42.5	6.9	41.5	SEP 11
MONTH									MONTH
JUL	96 60	87.5	4.5	88.0	41 55	54.9	6.9	55.0	JUL
AUG	99 69	88.1	4.8	88.0	38 52	49.0	6.4	48.0	AUG

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240303 SAINT MARY RS

1951-1970

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUN 11	8	48.3	10.2	48.5	60.6 57	32.4 61
JUN 21	13	44.3	12.0	45.0	68.4 52	24.4 61
JUL 1	15	43.1	12.2	42.0	68.4 55	24.7 60
JUL 11	19	37.0	8.9	37.0	58.3 52	22.8 60
JUL 21	18	33.7	10.3	31.0	53.5 55	19.2 60
AUG 1	19	38.3	10.0	39.0	61.0 56 M	21.0 59
AUG 11	19	34.0	8.7	32.0	46.9 51	17.3 67
AUG 21	19	41.7	12.5	41.0	70.8 51	22.5 67
SEP 1	16	47.3	12.1	45.5	73.7 64	31.5 58
SEP 11	8	52.3	10.1	53.0	66.3 54	38.7 56
MONTH						
JUL	19	37.1	9.0	37.0	56.1 55	22.1 60
AUG	19	38.1	8.1	38.0	53.1 51	23.4 67

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUN 11	100 64	79.5	12.6	79.0	16 60	27.4	8.7	25.0	JUN 11
JUN 21	94 55	72.4	22.9	86.0	11 58	26.1	11.9	23.0	JUN 21
JUL 1	94 64	73.5	16.9	68.0	13 60	24.6	8.9	23.0	JUL 1
JUL 11	100 52	63.6	18.3	66.0	8 70	21.3	7.6	22.0	JUL 11
JUL 21	90 62	61.2	19.8	61.5	6 54	18.3	7.4	18.0	JUL 21
AUG 1	94 52	72.6	17.7	80.0	6 61	19.7	5.9	20.0	AUG 1
AUG 11	89 57	61.9	20.1	58.0	7 69	17.9	5.5	17.0	AUG 11
AUG 21	100 54	69.4	17.5	68.0	11 67	20.7	6.5	22.0	AUG 21
SEP 1	100 64	81.3	15.6	85.5	8 69	25.2	8.0	26.5	SEP 1
SEP 11	100 64	86.8	9.7	89.5	16 59	23.5	7.0	22.0	SEP 11
MONTH									MONTH
JUL	100 52	77.3	16.9	82.0	6 54	16.6	6.5	18.0	JUL
AUG	100 54	80.8	12.6	83.0	6 61	15.3	5.3	15.0	AUG

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240303 SAINT MARY RS

1974-1983

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	6	66.3	6.3	64.5	76.5 75	59.9 82 M
JUL 11	9	68.3	4.7	67.0	73.5 74	61.0 80
JUL 21	9	71.6	4.8	73.0	77.2 74	61.0 81 M
AUG 1	9	70.0	3.7	70.0	74.6 79	65.0 77
AUG 11	10	66.6	6.5	65.0	80.5 81	59.2 78
AUG 21	10	63.6	5.8	63.0	73.7 81 M	56.4 77
MONTH						
JUL	5	69.6	4.5	71.0	73.9 75	62.6 81 M
AUG	9	66.3	4.5	66.0	76.1 81 M	61.0 80 M

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	89 75	77.8	7.6	76.5	43 81	52.0	6.9	53.0	JUL 1
JUL 11	92 79	80.8	7.1	85.0	50 82	53.8	4.0	52.0	JUL 11
JUL 21	87 79	82.7	4.8	83.0	48 79	57.8	8.1	58.0	JUL 21
AUG 1	89 74	80.8	4.7	80.0	47 74	57.0	7.5	56.0	AUG 1
AUG 11	88 81	77.4	5.6	76.0	45 78	53.3	9.1	51.0	AUG 11
AUG 21	85 81	74.6	7.4	74.5	45 81	50.5	4.9	49.0	AUG 21
MONTH									MONTH
JUL	92 79	84.6	4.6	85.0	43 81	49.0	4.6	50.0	JUL
AUG	89 74	82.7	4.6	84.0	45 81	47.1	2.0	47.0	AUG

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240303 SAINT MARY RS

1974-1983

10-DAY AND MONTHLY PERIOD MEANS

PRD. BEGINS	NO. YRS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR
JUL 1	6	45.7	9.4	45.0	57.3 82 M	33.0 76
JUL 11	9	46.3	8.7	45.0	56.8 83 M	31.0 74
JUL 21	9	42.8	11.2	40.0	64.7 81 M	27.2 74
AUG 1	9	43.1	6.6	40.0	55.0 76	36.3 79
AUG 11	10	49.8	9.3	49.0	64.4 80	37.8 83
AUG 21	10	51.1	6.9	51.0	59.7 79	41.9 83 M
MONTH						
JUL	5	42.9	9.7	40.0	58.5 81 M	33.2 74
AUG	9	48.8	4.5	49.0	55.7 80 M	41.7 81 M

10-DAY AND MONTHLY EXTREME DAILY VALUES

PRD. BEGINS	HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	95 75	76.2	17.3	78.5	15 74	24.8	8.9	24.0	JUL 1
JUL 11	94 76	73.3	12.9	76.0	18 76	28.9	8.4	31.0	JUL 11
JUL 21	100 79	76.9	21.5	84.0	15 78	22.3	5.5	[illegible].0	JUL 21
AUG 1	87 74	73.9	11.9	78.0	17 74	24.8	5.3	24.0	AUG 1
AUG 11	100 78	81.8	14.5	85.5	15 82	26.9	7.4	25.0	AUG 11
AUG 21	100 81	81.0	14.1	81.0	24 74	31.3	6.4	29.5	AUG 21
MONTH									MONTH
JUL	100 79	86.6	15.0	94.0	15 78	19.4	4.7	19.0	JUL
AUG	100 81	92.1	8.1	89.0	15 82	22.6	5.9	23.0	AUG

(con.)

Table 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240206 DESERT MTN LO

1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW
JUL 1	17	60.7	6.9	61.0	72.5 68	45.5 55	81 70	73.0	4.6	73.0	30 55	46.3	8.0	45.0
JUL 11	20	66.7	5.8	66.0	78.8 60	57.7 52	88 53	77.3	4.7	77.0	42 63	53.9	9.4	53.5
JUL 21	20	67.8	4.8	68.0	74.2 56	56.9 70	85 59	77.6	3.8	78.0	38 54	52.5	9.4	52.0
AUG 1	20	65.5	5.2	67.0	73.7 61	55.2 62	86 61	76.8	4.5	77.5	38 56	49.1	6.9	48.5
AUG 11	20	66.1	6.7	66.0	81.8 67	54.7 68 M	85 67	75.7	5.3	76.0	37 66	53.0	10.6	51.5
AUG 21	18	59.0	8.7	57.5	73.0 70	45.0 60 M	91 69	74.2	8.1	73.0	36 60	45.3	8.7	41.0
MONTH														
JUL	19	65.5	3.2	65.0	73.5 60	60.2 55	88 53	79.8	3.4	80.0	30 55	43.7	6.6	42.0
AUG	18	63.7	5.3	61.5	73.8 67	54.5 64	91 69	80.3	4.7	81.0	36 60	41.6	5.8	40.0

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240206 DESERT MTN LO

1951-1970

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW
JUL 1	17	51.7	14.9	54.0	83.5 55	26.9 60	100 69	82.3	19.2	88.0	10 60	28.1	10.3	29.0
JUL 11	20	43.1	8.9	42.5	61.1 63	28.5 60	100 70	70.4	18.8	67.5	12 67	24.3	6.6	23.5
JUL 21	20	38.3	11.7	36.0	68.8 70	25.1 53	100 70	70.6	23.4	72.5	11 60	21.1	6.7	20.5
AUG 1	20	44.2	13.3	39.5	68.6 70	25.2 59	100 70	80.8	19.2	84.0	11 61	23.9	8.2	23.0
AUG 11	20	39.5	12.6	38.0	68.5 68 M	17.6 67	100 68	69.3	23.4	68.0	9 69	21.6	8.5	22.0
AUG 21	18	50.6	17.4	47.5	87.3 54 M	23.8 69	100 66	82.3	22.3	93.0	13 57	24.3	11.2	21.0
MONTH														
JUL	19	43.2	8.2	42.0	64.0 55	28.8 60	100 70	90.5	11.7	93.0	10 60	19.0	5.4	20.0
AUG	18	43.9	9.7	43.5	59.4 60 M	25.7 67	100 70	92.4	13.7	100.0	9 69	16.6	4.5	16.0

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240219 FIREFIGHTER MTN LO

1975-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW
JUL 1	6	60.8	2.4	60.5	63.5 79	57.2 77	78 81	72.7	3.9	73.0	36 81	45.5	5.9	47.0
JUL 11	9	60.7	5.0	57.0	67.9 79	54.8 83	83 79	74.7	3.9	74.0	38 82	46.4	5.0	46.0
JUL 21	9	66.5	4.9	69.0	71.1 80	57.7 81	84 79	75.1	6.0	75.0	39 81	54.9	8.4	55.0
AUG 1	8	65.4	5.4	63.0	73.1 79	58.9 80	81 83	73.8	3.8	75.0	44 80	53.9	9.8	50.0
AUG 11	9	62.2	6.5	62.0	74.1 81	52.4 78	81 81	71.6	5.3	71.0	42 80	49.7	8.2	49.0
AUG 21	8	59.2	7.0	61.5	69.5 81	49.9 75	84 81	71.8	7.8	73.5	40 75	43.9	2.6	43.5
MONTH														
JUL	7	63.1	2.6	63.0	67.5 79	59.9 77	84 79	77.1	3.3	77.0	36 81	42.9	4.6	43.0
AUG	8	62.1	4.9	61.0	70.7 81	56.6 80	84 81	76.3	4.4	76.0	40 75	43.3	1.9	43.5

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION NUMBER 240219 FIREFIGHTER MTN LO

1975-1983

PRD. BEGINS	NO. YRS	10-DAY AND MONTHLY PERIOD MEANS MEAN	STD. DEV.	MEDIAN	HIGHEST AVG,YR	LOWEST AVG,YR	10-DAY AND MONTHLY EXTREME DAILY VALUES HIGH,YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW,YR	AVG. LOW	STD. DEV.	MEDIAN LOW
JUL 1	6	55.8	11.6	52.0	78.8 78 M	47.4 80	100 78	86.3	9.7	85.0	23 80	34.8	16.3	29.0
JUL 11	9	60.6	13.4	63.0	76.5 83	34.4 79	100 82	89.8	13.9	94.0	16 79	36.6	10.8	40.0
JUL 21	9	50.5	10.6	52.0	65.8 83 M	35.0 79	100 77	77.8	16.8	83.0	20 82	29.9	9.7	28.0
AUG 1	8	49.5	15.3	50.0	74.9 76	24.2 79	100 76	75.3	24.4	83.0	17 79	33.9	10.8	36.5
AUG 11	9	58.3	11.1	62.0	73.1 78	38.9 79	100 80	88.7	16.6	100.0	23 79	36.0	9.8	37.0
AUG 21	8	61.2	11.2	58.5	76.1 77	42.2 81	100 81	94.0	8.4	100.0	22 81	33.9	5.8	34.0
MONTH														
JUL	7	54.7	7.4	56.0	61.6 78 M	39.8 79	100 82	95.3	10.1	100.0	16 79	23.9	4.6	25.0
AUG	8	56.3	9.7	58.0	66.6 76	41.0 79	100 81	99.1	2.5	100.0	17 79	28.5	8.8	30.0

ble 33. (Con.)

DRY BULB TEMPERATURE

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION MT BROWN LO 1941-1958

	10-DAY AND MONTHLY PERIOD MEANS					10-DAY AND MONTHLY EXTREMES								
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG.YR	LOWEST AVG.YR	HIGH.YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW.YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	57.0	4.0	57.0	62.1 41	51.0 58	70 41	65.3	3.3	65.0	35 57	47.2	8.5	46.0	JUL 1
JUL 11	59.7	5.7	61.0	69.2 55	48.7 42	79 53	69.9	5.2	69.0	35 57	47.0	7.7	48.0	JUL 11
JUL 21	60.5	4.3	60.0	67.6 56	55.1 55	75 53	70.4	2.8	70.0	33 54	46.9	9.2	49.0	JUL 21
AUG 1	59.6	3.9	60.0	65.1 58	52.4 56	77 45	69.5	3.9	69.5	35 56	47.9	6.7	50.0	AUG 1
AUG 11	60.2	4.1	59.0	69.5 58	53.0 54	73 58	68.2	3.2	67.5	42 54	50.6	7.2	50.0	AUG 11
AUG 21	53.4	5.1	53.0	62.4 55	43.3 51	75 46	68.8	4.2	68.0	32 51	38.7	6.8	36.0	AUG 21
MONTH														MONTH
JUL	59.5	3.7	60.0	65.1 51	52.6 42	79 53	72.2	3.5	72.0	33 54	42.2	7.1	41.0	JUL
AUG	58.2	3.5	56.0	66.4 58	54.3 54	77 45	71.6	3.0	72.0	32 51	39.9	7.6	37.0	AUG

RELATIVE HUMIDITY

MEAN, STANDARD DEVIATION, AND EXTREME VALUES

STATION MT BROWN LO 1941-1958

	10-DAY AND MONTHLY PERIOD MEANS					10-DAY AND MONTHLY EXTREMES								
PRD. BEGINS	MEAN	STD. DEV.	MEDIAN	HIGHEST AVG.YR	LOWEST AVG.YR	HIGH.YR	AVG. HIGH	STD. DEV.	MEDIAN HIGH	LOW.YR	AVG. LOW	STD. DEV.	MEDIAN LOW	PRD. BEGINS
JUL 1	52.6	11.7	53.0	67.8 58	38.4 41	100 57	79.0	21.2	81.0	26 41	36.2	7.2	36.0	JUL 1
JUL 11	50.8	7.7	49.0	64.0 50	41.7 53	100 52	76.3	15.5	72.0	25 53	33.8	4.6	34.0	JUL 11
JUL 21	48.1	11.1	47.0	74.0 55	35.3 53	100 55	78.7	19.7	78.0	21 53	29.7	4.7	30.0	JUL 21
AUG 1	48.5	11.1	43.0	67.4 56	36.0 41	100 57	77.4	18.7	75.0	18 41	29.7	8.1	31.0	AUG 1
AUG 11	46.0	10.0	44.5	64.4 54	29.5 58	100 54	71.1	19.0	74.0	16 46	28.8	7.9	28.0	AUG 11
AUG 21	58.3	13.0	56.0	80.5 51	36.1 55	100 56	91.1	16.3	100.0	20 46	29.9	6.9	32.0	AUG 21
MONTH														MONTH
JUL	50.0	8.3	48.0	62.5 55	38.3 53	100 57	88.0	16.0	93.0	21 53	29.2	4.6	30.0	JUL
AUG	50.0	8.9	48.0	66.7 56	36.9 58	100 57	93.4	13.3	100.0	16 46	25.3	6.1	24.5	AUG

Table 34.--Frequency distribution of afternoon dry bulb temperature (°F) and relative humidity (percent); at 1600 m.s.t., based on years 1951-70 except as noted

DRY BULB TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

TEMPERATURE VALUES

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD BEGI
JUL 1										5	5	16	89	84	121	158	168	168	137	47			JUL
JUL 11													20	40	95	145	175	210	205	90	20		JUL
JUL 21												9	23	41	36	86	209	223	236	127	9		JUL
AUG 1												5	47	42	95	137	179	189	189	89	26		AUG
AUG 11												15	55	55	40	125	170	220	195	100	25		AUG
AUG 21											9	50	118	132	114	150	132	118	95	73	9		AUG
SEP 1										11	44	61	100	94	144	144	128	139	89	33	11		SEP
SEP 11									8	31	54	92	154	131	108	77	169	154	15	8			SEP
SEP 21										40	147	107	147	200	67	120	93	40	40				SEP
MONTH																							MON
JUL										2	2	8	43	54	82	128	185	202	195	90	10		J
AUG											3	25	75	79	84	138	159	174	157	87	20		A
SEP									3	23	68	81	127	127	117	117	135	125	55	18	5		S

RELATIVE HUMIDITY

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

HUMIDITY VALUES

PRD. BEGINS	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100	PR BEG
JUL 1			21	79	126	137	84	153	79	37	58	42	68	26	5	32	11	32	11			JUL
JUL 11				75	160	205	165	100	85	50	70	25	20	10	20	5	5		5			JUL
JUL 21		5	59	164	236	136	118	114	50	32	14	23	5	5	14		14	9	5			JUL
AUG 1		16	37	168	168	142	84	89	74	47	26	11	21	37	5	26	16	21	5		5	AUG
AUG 11		5	80	190	170	110	135	70	70	15	30	25	5	30	20	10	25	5	5			AUG
AUG 21		5	45	150	145	77	73	100	59	41	68	36	41	55	27	23	23	23	9			AUG
SEP 1		6	44	72	172	156	83	100	61	50	67	50	28	11	17	28	17	17	22			SEP
SEP 11		8		46	123	169	108	69	62	54	115	38	31	31	46	23	8	54	15			SEP
SEP 21		13	40	40	40	107	67	53	160	13	40	80	53	53	53	27	27	53	67		13	SEP
MONTH																						MO
JUL		2	28	108	177	159	123	121	70	39	46	30	30	13	13	11	10	13	7			J
AUG		8	54	169	161	108	97	87	67	34	43	25	23	41	18	20	21	16	7		2	A
SEP		8	29	57	130	151	88	81	81	44	78	52	34	26	34	26	16	36	29		3	S

Table 34. (Con.)

DRY BULB TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240217 HUNGRY HORSE RS (INCLUDES CORAM RS, 1951-1957) 1951-1970

TEMPERATURE VALUES

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
MAY 1									11	46	184	149	138	103	138	149	46	23	11				MAY 1
MAY 11									47	47	103	65	112	159	187	150	112	19					MAY 11
MAY 21									7	34	62	117	138	159	138	138	97	83	28				MAY 21
JUN 1										6	40	69	120	171	217	143	131	74	29				JUN 1
JUN 11										5	22	82	120	158	131	191	137	104	38	11			JUN 11
JUN 21											45	73	73	147	147	186	147	96	85				JUN 21
JUL 1										5	11	21	48	116	79	164	153	201	159	42			JUL 1
JUL 11												10	55	75	106	186	211	246	85	20	5		JUL 11
JUL 21												5	14	55	32	64	195	227	295	100	14		JUL 21
AUG 1												5	25	40	90	130	150	225	205	110	10	10	AUG 1
AUG 11												15	40	55	50	100	160	260	210	80	30		AUG 11
AUG 21											14	68	77	118	141	155	136	136	77	68	5	5	AUG 21
SEP 1										10	25	86	81	121	126	197	116	126	91	15	5		SEP 1
SEP 11									10	57	26	161	93	119	130	135	150	104	10	5			SEP 11
SEP 21									6	76	76	111	146	140	105	146	117	47	29				SEP 21
OCT 1								24	24	48	79	183	198	135	135	143	32						OCT 1
OCT 11									56	120	278	194	167	148	19	19							OCT 11
OCT 21						9	9	84	178	215	159	178	131	37									OCT 21
MONTH																							MONTH
MAY									21	41	106	109	130	145	153	145	88	47	15				MAY
JUN										4	36	75	105	159	164	174	138	92	50	4			JUN
JUL										2	3	8	23	74	61	109	179	214	237	77	12	2	JUL
AUG											5	31	48	73	95	129	148	205	161	85	15	5	AUG
SEP									5	46	41	119	105	126	121	160	128	94	44	7	2		SEP
OCT						3	3	35	82	123	167	185	167	109	56	59	12						OCT

RELATIVE HUMIDITY

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240217 HUNGRY HORSE RS (INCLUDES CORAM RS, 1951-1957) 1951-1970

HUMIDITY VALUES

PRD. BEGINS	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100	PRD. BEGINS
MAY 1			46	57	149	184	34	92	57	34	57	69	46	34	57	23	11	34	11			MAY 1
MAY 11				84	140	121	150	112	75	56	37	56	9	37	28	19	28	37	9			MAY 11
MAY 21			21	55	110	138	97	90	62	90	110	28	21	34	41	34	21	28	21			MAY 21
JUN 1		6		29	57	86	183	131	109	80	69	57	17	23	17	23	34	46	23	11		JUN 1
JUN 11			11	22	38	164	158	153	82	66	44	44	27	44	33	33	27	38	16			JUN 11
JUN 21			6	51	85	164	181	107	85	40	45	45	34	11	17	11	28	40	28	11	11	JUN 21
JUL 1			26	63	138	164	153	116	69	37	69	26	32	21	5	16	21	11	26	5		JUL 1
JUL 11			45	75	176	261	146	106	30	60	30	25	10	10	5			15	5			JUL 11
JUL 21		14	105	173	205	205	109	55	36	14	27	5	14	5		9	9	14	5			JUL 21
AUG 1		5	100	170	155	195	85	85	35	5	30	40	15	10		25	20	5	20			AUG 1
AUG 11		25	100	160	235	165	90	60	45	15	15	20	10	5	15	15	5	15	5			AUG 11
AUG 21		5	50	132	100	141	100	86	91	32	50	36	18	32	14	27	36	18	27		5	AUG 21
SEP 1			40	106	111	131	121	96	101	61	56	20	35	10	15	35	15	15	20		10	SEP 1
SEP 11		5		47	114	166	109	93	88	83	62	26	26	26	31	41	31	26	26			SEP 11
SEP 21			12	41	70	123	105	76	111	135	70	70	23	29	12	23	23	41	23	6	6	SEP 21
OCT 1			8	8	63	127	111	71	103	56	95	71	40	40	48	48	8	48	32	8	16	OCT 1
OCT 11				9	9	56	111	102	83	93	93	93	37	65	93	28	28	37	65			OCT 11
OCT 21					9		56	56	47	84	84	65	94	56	103	93	93	37	121		9	OCT 21
MONTH																						MONTH
MAY			21	65	130	145	97	97	65	65	74	47	24	35	41	27	21	32	15			MAY
JUN		2	6	34	60	138	174	131	92	62	52	49	26	26	22	22	30	41	22	7	4	JUN
JUL		5	61	107	174	211	135	90	44	36	41	18	18	12	3	8	10	13	12	2		JUL
AUG		11	82	153	161	166	92	77	58	18	32	32	15	16	10	23	21	13	18		2	AUG
SEP		2	18	66	100	141	112	89	100	91	62	37	28	21	20	34	23	27	23	2	5	SEP
OCT			3	6	29	65	94	76	79	76	91	76	53	53	79	56	41	41	70	3	9	OCT

(con.)

Table 34. (Con.)

DRY BULB TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240301 BELLY RIVER RS 1951-1970

TEMPERATURE VALUES

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGIN
JUN 21									8	40	111	119	190	198	151	119	48	16					JUN 2
JUL 1										12	24	88	129	106	182	200	176	82					JUL
JUL 11											5	30	75	100	165	200	270	110	35	10			JUL 1
JUL 21											14	23	73	86	155	218	286	114	23	9			JUL 2
AUG 1											16	42	89	105	137	237	179	147	37	5	5		AUG
AUG 11										5	35	35	75	101	151	216	231	95	45	10			AUG 1
AUG 21									5	23	77	105	100	200	114	155	118	82	18	5			AUG 2
SEP 1								18	41	53	94	88	112	106	171	106	124	76	6	6			SEP
SEP 11							10	21	21	73	104	115	83	177	135	177	52	21	10				SEP 1
MONTH																							MONT
JUL										3	14	44	90	97	166	207	249	103	20	7			JUL
AUG									2	10	44	62	89	138	133	200	174	107	33	7	2		AUG

RELATIVE HUMIDITY

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240301 BELLY RIVER RS 1951-1970

HUMIDITY VALUES

PRD. BEGINS	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100	PRD BEGI
JUN 21			8	16	48	63	56	111	63	119	111	71	56	48	40	16	40	24	95		16	JUN
JUL 1					41	88	147	124	129	100	47	76	47	29	59	29	53	24	6			JUL
JUL 11				15	70	125	165	140	125	100	65	40	55	20	25	10	20	10	15			JUL
JUL 21			14	27	109	150	145	141	73	64	41	68	41	32	45	14	18	9	9			JUL
AUG 1		5	5	74	100	132	126	105	84	89	42	53	26	26	21	16	32	32	32			AUG
AUG 11			30	30	121	196	111	85	90	60	45	65	45	15	20	30	15	15	25			AUG
AUG 21			9	36	114	105	91	82	64	109	95	59	45	41	18	41	36	14	36		5	AUG
SEP 1			6	35	88	71	112	112	88	76	71	76	24	18	18	41	41	29	65	6	24	SEP
SEP 11				21	63	73	125	115	146	52	63	73	42	21	42	21	10	31	63		42	SEP
MONTH																						MON
JUL			5	15	76	124	153	136	107	86	51	61	47	27	42	17	29	14	10			J
AUG		2	15	46	112	143	108	90	79	87	62	59	39	28	20	30	28	20	31		2	A

DRY BULB TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240303 SAINT MARY RS 1951-1970

TEMPERATURE VALUES

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRI BEG
JUN 11										12	62	123	160	173	173	123	99	62	12				JUN
JUN 21										8	39	78	180	180	164	188	94	55	16				JUN
JUL 1										13	7	53	160	153	127	207	127	93	53	7			JUL
JUL 11											11	21	32	53	121	226	247	174	84	21	11		JUL
JUL 21												25	30	71	91	167	237	258	101	20			JUL
AUG 1											11	37	53	117	96	149	223	191	85	32	5		AUG
AUG 11										5	5	32	32	79	132	200	232	179	84	21			AUG
AUG 21									5	14	62	86	86	148	177	110	129	129	48		5		AUG
SEP 1								13	38	64	64	108	153	127	127	146	96	51	13				SEP
SEP 11								13	63	75	88	163	138	100	113	213	13	25					SEP
MONTH																							MON
JUL										4	6	32	67	87	112	199	210	182	82	17	4		L
AUG									2	7	27	53	58	116	136	152	193	165	72	17	3		G

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Table 34. (Con.)

RELATIVE HUMIDITY

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240303 SAINT MARY RS 1951-1970

HUMIDITY VALUES

PRD. BEGINS	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100	PRD. BEGINS
JUN 11				25	49	99	86	148	74	111	62	111	37	62	12	49	12	37			25	JUN 11
JUN 21			16	23	78	86	156	109	133	63	78	78	47	23	31	8		47	23			JUN 21
JUL 1			13	93	73	93	80	167	100	40	67	67	40	73	20	7	20	20	27			JUL 1
JUL 11		5	32	42	142	137	168	116	111	74	32	58	5	26	16	11	11	11			5	JUL 11
JUL 21		5	40	146	177	167	96	91	66	35	35	51	25	20	10	10		15	10			JUL 21
AUG 1		5	27	96	165	122	133	90	69	32	96	27	21	21	21	5	27	37	5			AUG 1
AUG 11		11	63	100	168	147	111	95	89	53	53	42	5	11	5	16	11	21				AUG 11
AUG 21			19	72	129	144	53	110	96	81	53	33	38	72	19	24	19	19	14		5	AUG 21
SEP 1		6	19	19	64	127	108	121	70	70	76	45	32	64	13	45	25	45	32		19	SEP 1
SEP 11				25	100	113	38	75	88	100	63	38	25	50	50	88	25	25	75		25	SEP 11
MONTH																						MONTH
JUL		4	30	95	136	136	117	121	91	50	43	58	22	37	15	9	9	15	11		2	JUL
AUG		5	36	89	153	138	97	99	85	56	66	34	22	36	15	15	19	26	7		2	AUG

DRY BULB TEMPERATURE

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN LO 1951-1970

TEMPERATURE VALUES

PRD. BEGINS	BELOW 0	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100 AND ABOVE	PRD. BEGINS
JUL 1								12	6	59	112	95	112	195	148	148	101	12					JUL 1
JUL 11										15	40	60	100	165	165	245	155	45	10				JUL 11
JUL 21									5	18	36	36	59	127	205	277	205	27	5				JUL 21
AUG 1									5	25	45	85	100	145	220	200	115	55	5				AUG 1
AUG 11									10	10	56	61	56	158	245	209	117	71	5				AUG 11
AUG 21									36	115	94	104	120	156	151	99	68	42	10	5			AUG 21
MONTH																							MONTH
JUL								3	3	29	59	61	88	160	175	229	158	29	5				JUL
AUG									17	49	65	83	92	153	206	170	100	56	7	2			AUG

RELATIVE HUMIDITY

PERCENTAGE FREQUENCY DISTRIBUTION OF DAILY VALUES
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN LO 1951-1970

HUMIDITY VALUES

PRD. BEGINS	0 TO 4	5 TO 9	10 TO 14	15 TO 19	20 TO 24	25 TO 29	30 TO 34	35 TO 39	40 TO 44	45 TO 49	50 TO 54	55 TO 59	60 TO 64	65 TO 69	70 TO 74	75 TO 79	80 TO 84	85 TO 89	90 TO 94	95 TO 99	100	PRD. BEGINS
JUL 1			12	6	65	95	118	71	71	101	47	118	41	30	47	12	41	47	36		41	JUL 1
JUL 11			5	20	60	115	195	115	110	105	70	40	20	60	20	25	5		30		5	JUL 11
JUL 21			27	27	164	150	191	141	59	45	45	32	14	14	14	14	14	9	18		23	JUL 21
AUG 1			10	40	110	145	160	100	60	50	45	60	30	15	35	30	25	25	15		45	AUG 1
AUG 11		5	26	87	133	122	168	107	92	56	41	15	26	20	15	10	10	10	46		10	AUG 11
AUG 21			10	42	141	78	120	57	73	78	63	36	21	26	57	5	21	42	42		89	AUG 21
MONTH																						MONTH
JUL			15	19	100	122	171	112	80	81	54	59	24	34	25	17	19	17	27		22	JUL
AUG		2	15	56	128	116	150	88	75	61	49	37	26	20	36	15	19	26	34		48	AUG

Table 35.--Windspeed (mi/h), average and frequency distribution by direction; at about 1600 m.s.t., based on years 1951-70 except as noted (1300 m.s.t. data beginning in 1974)

WIND SPEED - DIRECTION
PERCENTAGE FREQUENCY OF OCCURRENCE BY DIRECTION FOR SELECTED SPEED INCREMENTS
-GIVEN TO TENTHS PERCENT. DECIMAL POINT OMITTED

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

MONTH JUL

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	3	6	1	2									4	7	3.8
E															
SE															
S	7	13	12	22	11	21	2	4					32	60	6.6
SW	113	212	177	331	72	135	14	26			1	2	377	706	5.6
W	18	34	28	52	16	30	2	4					64	120	5.7
NW	10	19	11	21	6	11	1	2					28	52	5.4
N	1	2	2	4	5	9	1	2					9	17	8.1
CLM	20	37											20	37	.0
TOT	172	322	231	433	110	206	20	37			1	2	534		5.5

MONTH AUG

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	1	2	2	4									3	5	3.7
E	2	4											2	4	3.0
SE															
S	3	5	9	16	10	18							22	39	7.1
SW	95	167	197	347	81	143	14	25					387	681	5.6
W	13	23	52	92	23	40	1	2					89	157	5.9
NW	3	5	16	28	6	11	2	4					27	48	6.7
N	4	7	4	7	4	7							12	21	5.9
CLM	26	46											26	46	.0
TOT	147	259	280	493	124	218	17	30					568		5.5

STATION NUMBER 240217 HUNGRY HORSE RS 1958-1970

MONTH JUN

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	8	26	12	39	2	6							22	71	4.1
E	10	32	6	19	1	3	1	3					18	58	4.2
SE	6	19	8	26	8	26							22	71	5.5
S	8	26	7	23	4	13							19	62	5.1
SW	5	16	10	32	6	19							21	68	6.1
W	14	45	19	62	12	39	3	10	1	3			49	159	6.2
NW	12	39	49	159	23	75	2	6					86	279	6.2
N	9	29	31	101	24	78	2	6			1	3	67	218	6.9
CLM	4	13											4	13	.0
TOT	76	247	142	461	80	260	8	26	1	3	1	3	308		5.9

MONTH JUL

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	12	31	11	29	4	10	1	3					28	73	4.9
E	5	13	6	16	3	8							14	37	4.7
SE	7	18	4	10	4	10							15	39	4.4
S	2	5	5	13	4	10	1	3					12	31	6.7
SW	6	16	8	21	1	3	1	3					16	42	4.9
W	13	34	36	94	18	47	2	5	1	3			70	184	6.5
NW	19	50	76	199	32	84			1	3			128	336	6.1
N	10	26	43	113	40	105	4	10	1	3			98	257	7.2
CLM															
TOT	74	194	189	496	106	278	9	24	3	8			381		6.2

MONTH AUG

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	10	26	5	13	4	10	1	3					20	51	4.8
E	6	15	8	21	3	8							17	44	4.5
SE	9	23	8	21	3	8	1	3					21	54	5.2
S	6	15	11	28	7	18			1	3			25	64	6.4
SW	10	26	9	23	3	8							22	57	4.5
W	19	49	40	103	11	28	2	5					72	185	5.4
NW	36	93	69	177	24	62	5	13					134	344	5.6
N	14	36	29	75	31	80	4	10					78	201	6.9
CLM															
TOT	110	283	179	460	86	221	13	33	1	3			389		5.7

MONTH SEP

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	13	40	6	18	1	3	1	3					21	64	4.0
E	8	24	3	9	3	9	1	3					15	46	4.7
SE	9	28	9	28	4	12							22	67	4.8
S	31	95	9	28	4	12							44	135	3.2
SW	21	64	18	55	3	9							42	128	4.0
W	29	89	35	107	7	21	2	6					73	223	4.8
NW	32	98	32	98	9	28	1	3					74	226	4.5
N	9	28	18	55	8	24	1	3					36	110	5.6
CLM															
TOT	152	465	130	398	39	119	6	18					327		4.4

STATION NUMBER 240301 BELLY RIVER RS 1951-1970

MONTH JUL

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	10	18	21	37	3	5							34	60	4.6
E	1	2											1	2	2.0
SE	1	2	5	9	4	7	3	5					13	23	9.0
S	5	9	33	58	65	115	28	49	9	16	2	4	142	251	10.5
SW	13	23	78	138	138	244	51	90	5	9	2	4	287	507	9.6
W	1	2	5	9	12	21	6	11					24	42	9.6
NW	2	4	5	9	2	4							9	16	6.1
N	14	25	27	48	7	12							48	85	4.8
CLM	8	14											8	14	.0
TOT	55	97	174	307	231	408	88	155	14	25	4	7	566		8.9

MONTH AUG

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	8	13	14	23	2	3							24	40	4.6
E	1	2	2	3	1	2							4	7	5.2
SE			3	5	5	8	2	3	1	2			11	18	9.7
S	11	18	32	54	67	112	29	49	3	5			142	238	9.4
SW	21	35	61	102	120	201	72	121	11	18	3	5	288	483	10.3
W	1	2	8	13	9	15	5	8	1	2			24	40	10.0
NW	2	3	9	15	1	2							12	20	5.3
N	28	47	40	67	10	17							78	131	4.6
CLM	13	22											13	22	.0
TOT	85	143	169	284	215	361	108	181	16	27	3	5	596		8.7

STATION NUMBER 240303 ST MARY RS 1951-1970

MONTH JUL

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE			7	14	9	18	2	4					18	37	8.4
E			10	20	7	14	3	6					20	41	8.8
SE	1	2	4	8	4	8							9	18	7.3
S	5	10	6	12	6	12	3	6	1	2			21	43	7.7
SW	12	24	55	112	112	228	42	85	6	12			227	461	9.7
W	23	47	44	89	63	128	18	37	2	4			150	305	8.1
NW	3	6	7	14	11	22			1	2			22	45	8.0
N	6	12	8	16	4	8	2	4	1	2			21	43	6.7
CLM	4	8											4	8	.0
TOT	54	110	141	287	216	439	70	142	11	22			492		8.7

MONTH AUG

DIR.	0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	3	6	14	27	11	21	1	2					29	56	7.2
E	3	6	8	15	8	15	3	6					22	42	7.4
SE	3	6	4	8	9	17	1	2					17	33	8.3
S	1	2	7	13	10	19	5	10					23	44	9.1
SW	20	38	52	100	141	271	50	96	5	10	2	4	270	518	9.7
W	11	21	26	50	61	117	26	50	2	4			126	242	9.7
NW	3	6	2	4	4	8	1	2			1	2	11	21	8.5
N	1	2	5	10	9	17	1	2					16	31	7.6
CLM	7	13											7	13	.0
TOT	52	100	119	226	253	486	88	169	7	13	3	6	521		9.2

(con.)

Table 35. (Con.)

WIND SPEED - DIRECTION
PERCENTAGE FREQUENCY OF OCCURRENCE BY DIRECTION FOR SELECTED SPEED INCREMENTS
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240202 BIG CREEK R.S. 1964-1982

MONTH JUN

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	11	71	9	58	3	19							23	149	4.2
E	2	13	3	19									5	32	4.6
SE	25	162	27	175	8	52							60	390	4.6
S			1	6									1	6	5.0
SW	10	65	12	78	5	32							27	175	4.7
W	6	39	6	39									12	78	3.8
NW	13	84	7	45	1	6	1	6					22	143	3.8
N	4	26											4	26	2.0
LM															
OT	71	461	65	422	17	110	1	6					154		4.3

MONTH JUL

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	22	43	20	39	13	25	1	2	1	2			57	110	5.1
E	7	14	12	23	8	15							27	52	5.7
SE	61	118	72	139	40	77	10	19			1	2	184	356	5.8
S	8	15	14	27	5	10							27	52	4.8
SW	31	60	30	58	17	33	1	2					79	153	5.1
W	23	44	30	58	14	27							67	130	4.9
NW	25	48	16	31	9	17	2	4					52	101	4.6
N	10	19	7	14	2	4	1	2					20	39	4.3
LM	4	8											4	8	.0
OT	191	369	201	389	108	209	15	29	1	2	1	2	517		5.2

MONTH AUG

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	10	19	42	80	5	10							57	109	5.2
E	9	17	19	36	17	33							45	86	6.0
SE	47	90	61	117	45	86	6	11					159	305	6.0
S	11	21	19	36	8	15	2	4					40	77	6.0
SW	21	40	36	69	19	36	3	6			1	2	80	153	6.1
W	23	44	29	56	9	17	2	4					63	121	5.1
NW	19	36	26	50	4	8	2	4					51	98	5.0
N	9	17	7	13	2	4	1	2					19	36	4.6
LM	8	15											8	15	.0
OT	157	301	239	458	109	209	16	31			1	2	522		5.6

MONTH SEP

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	12	33	22	60	10	27	2	5	1	3			47	127	6.0
E	4	11	11	30	7	19			1	3			23	62	6.6
SE	38	103	54	146	29	79	2	5					123	333	5.3
S	6	16	11	30	10	27	1	3					28	76	6.4
SW	21	57	18	49	10	27	1	3					50	136	5.2
W	15	41	15	41	11	30	1	3					42	114	5.7
NW	17	46	11	30	2	5							30	81	3.8
N	11	30	7	19	4	11							22	60	4.2
LM	4	11											4	11	.0
OT	128	347	149	404	83	225	7	19	2	5			369		5.3

STATION NUMBER 240207 WEST GLACIER 1963-1982

MONTH JUN

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	7	20	20	56	4	11							31	87	4.9
E	9	25	7	20	5	14							21	59	4.6
SE	7	20	12	34	2	6							21	59	4.8
S	6	17	16	45	8	23	2	6					32	90	6.3
SW	29	82	69	194	44	124	8	23					150	423	6.5
W	15	42	23	65	21	59	8	23					67	189	7.0
NW	8	23	9	25									17	48	3.8
N	7	20	7	20	2	6							16	45	4.4
LM															
OT	88	248	163	459	86	242	18	51					355		6.0

MONTH JUL

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	6	12	13	26	5	10	1	2					25	49	5.5
E	12	24	10	20	3	7	1	2					24	47	4.4
SE	3	6	17	33	4	8			1	2			25	49	6.4
S	13	26	13	26	10	20	1	2					37	73	5.8
SW	69	136	123	242	65	128	22	43					279	548	6.2
W	20	39	28	55	22	43	8	16	1	2			79	155	6.9
NW	6	12	10	20	4	8	1	2					21	41	6.0
N	7	14	4	8	4	8	2	4					17	33	5.7
LM	2	4											2	4	.0
OT	138	271	218	428	115	226	36	71	2	4			509		6.2

MONTH AUG

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	14	27	25	49	4	8	1	2					44	86	4.8
E	7	14	12	23	4	8	1	2					24	47	5.2
SE	3	6	7	14	4	8							14	27	5.4
S	5	10	29	57	2	4	2	4					38	74	6.0
SW	60	117	109	213	75	147	23	45	1	2			268	524	6.8
W	8	16	35	68	15	29	5	10					63	123	6.8
NW	10	20	16	31	7	14							33	65	5.2
N	5	10	15	29	5	10							25	49	5.6
LM	2	4											2	4	.0
OT	114	223	248	485	116	227	32	63	1	2			511		6.3

MONTH SEP

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	3	12	11	44	1	4							15	60	5.1
E	4	16	12	48	4	16							20	81	5.4
SE	7	28	6	24									13	52	4.3
S	2	8	2	8	2	8							6	24	5.8
SW	31	125	60	242	36	145	6	24	2	8			135	544	6.3
W	4	16	23	93	14	56	3	12					44	177	7.1
NW	3	12	4	16	1	4							8	32	5.0
N	4	16	3	12									7	28	4.1
LM															
OT	58	234	121	488	58	234	9	36	2	8			248		6.1

STATION NUMBER 240206 DESERT MTN 1951-1970

MONTH JUL

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	12	21	6	10	2	3					2	3	22	38	5.7
E	10	17	16	28	2	3							28	49	4.4
SE	4	7	6	10	1	2							11	19	3.8
S	8	14	10	17	1	2							19	33	4.2
SW	46	80	174	303	50	87	5	9					275	479	5.7
W	28	49	104	181	62	108	4	7	1	2			199	347	6.4
NW	3	5	12	21	1	2							16	28	5.1
N	2	3											2	3	3.0
LM	2	3											2	3	.0
OT	115	200	328	571	119	207	9	16	1	2	2	3	574		5.7

MONTH AUG

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	7	12	10	17	4	7							21	36	4.7
E	16	28	14	24	2	3							32	55	3.7
SE	6	10	2	3	1	2							9	16	3.8
S	1	2	6	10									7	12	4.6
SW	48	83	178	308	64	111	7	12					297	515	6.0
W	41	71	89	154	61	106	3	5	1	2			195	338	6.3
NW	1	2	10	17	4	7							15	26	5.9
N	1	2											1	2	3.0
LM															
OT	121	210	309	536	136	236	10	17	1	2			577		5.8

MT BROWN LO 1941-1958

MONTH JUL

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	2	6	4	13									6	19	3.7
E	1	3	1	3	2	6	1	3					5	16	9.2
SE	7	22	8	25	5	16	1	3					21	66	5.9
S	3	9	5	16	3	9	1	3	2	6			14	44	8.2
SW	14	44	54	170	83	261	34	107	10	31	1	3	196	616	9.8
W	6	19	21	66	22	69	7	22			1	3	57	179	8.3
NW	6	19	3	9	5	16	1	3	1	3			16	50	7.0
N	3	9											3	9	2.3
LM															
OT	42	132	96	302	120	377	45	142	13	41	2	6	318		8.8

MONTH AUG

DIR.	WIND SPEED, MPH 0-3 N.	PCT	4-7 N.	PCT	8-12 N.	PCT	13-18 N.	PCT	19-24 N.	PCT	>24 N.	PCT	TOTAL N.	PCT	AVG SPEED
NE	2	5	1	3	3	8	1	3					7	18	8.1
E	2	5	2	5	3	8	4	10	3	8			14	36	12.4
SE	7	18	10	26	4	10	2	5					23	60	5.9
S	1	3	19	49	5	13	4	10	1	3			30	78	8.3
SW	20	52	71	184	68	177	41	106	15	39	4	10	219	569	9.9
W	4	10	18	47	24	62	8	21	1	3	1	3	56	145	9.2
NW	12	31	9	23	5	13	1	3					27	70	5.4
N	3	8	1	3			1	3					5	13	5.4
LM	4	10											4	10	.0
OT	55	143	131	340	112	291	62	161	20	52	5	13	385		9.0

(con.)

Table 36.--Frequency distribution of three-way combinations of dry bulb temperature (°F), relative humidity (percent), and windspeed (mi/h); at 1600 m.s.t., based on years 1951-70 except as noted

TEMPERATURE - RELATIVE HUMIDITY - WINDSPEED
PERCENTAGE FREQUENCY OF OCCURRENCE FOR SELECTED COMBINATIONS
GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

MONTH JUL

TEMP, DEG F	WIND SPEED 0-4 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99		4								
90-94		7	16	5						
85-89		21	39	14						
80-84		4	30	23	7	2				
75-79		4	32	32	11	4				
70-74		2	16	21	12	9	4			
65-69				12	5	27	5	4	2	
60-64					4	7	14	4		
55-59					5	5	5	7	2	5
50-54						2		2	9	
45-49									2	
40-44									2	
35-39										
30-34										
<30										
TOTAL		41	133	109	44	55	28	16	12	5
NUMBER	0	23	75	61	25	31	16	9	7	3

TEMP, DEG F	WIND SPEED 5-9 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99			5	2						
90-94			27	20						
85-89	2	36	50	12						
80-84	2	14	48	32	9					
75-79		9	30	27	21					
70-74			14	21	9			2		
65-69			2	2	5	4		4		
60-64				2	2	7		5		
55-59						2	2		4	
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	4	91	165	96	46	12	2	11	4	
NUMBER	2	51	93	54	26	7	1	6	2	0

TEMP, DEG F	WIND SPEED 10-14 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94	4	7	5	2						
85-89		16	7	4						
80-84		7	9	4	2					
75-79			5	5	2					
70-74			5	4	2					
65-69			4	5						
60-64					2		2		2	
55-59					2	2				
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	4	30	36	23	9	2	2		2	
NUMBER	2	17	20	13	5	1	1	0	1	0

TEMP, DEG F	WIND SPEED 15-19 MPH	WIND SPEED GREATER/EQUAL 20 MPH	TOTAL	NUMBER
<100				0
95-99				
90-94	2	2	11	6
85-89	2		96	54
80-84	5 2		203	114
75-79	4 2		199	112
70-74			187	105
65-69			121	68
60-64			80	45
55-59			50	28
50-54			41	23
45-49			9	5
40-44			2	1
35-39			2	1
30-34				0
<30				0
TOTAL	4 9 4	2	1000	
NUMBER	0 2 5 2 0 0 0 0 0 0	0 0 1 0 0 0 0 0 0 0		562

STATION NUMBER 240210 POLEBRIDGE RS 1951-1970

MONTH AUG

TEMP, DEG F	WIND SPEED 0-4 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99		9								
90-94		17	3							
85-89		15	19							
80-84	2	9	19	17	3					
75-79		9	34	22	10					
70-74		3	10	19	22	12	5			
65-69			3	9	9	14	2	7	2	
60-64				2	3	10	10	3	5	
55-59					3	2	14	15	10	3
50-54					3	2			3	3
45-49									3	
40-44										
35-39										
30-34										
<30										
TOTAL	2	62	89	69	55	39	31	26	24	7
NUMBER	1	36	52	40	32	23	18	15	14	4

TEMP, DEG F	WIND SPEED 5-9 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99	3									
90-94		45	3							
85-89		70	31	10						
80-84	3	24	60	14	3					
75-79		14	34	22	2					
70-74		2	14	26	9	3	3			
65-69			3	14	10	5	2			
60-64				9	10	3	14		2	
55-59					2	3	3	3		
50-54							5	3	2	
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	7	154	146	94	36	15	27	7	5	
NUMBER	4	90	85	55	21	9	16	4	2	0

TEMP, DEG F	WIND SPEED 10-14 MPH: RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99	3	3								
90-94		19		2						
85-89		10	5	2						
80-84		9	12	2						
75-79			5	2						
70-74		2	2	7		2				
65-69				2	2					
60-64					2					2
55-59							2	2		
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	3	43	24	15	5	2	2	2		2
NUMBER	2	25	14	9	2	1	1	1	0	1

TEMP, DEG F	WIND SPEED 15-19 MPH	WIND SPEED GREATER/EQUAL 20 MPH	TOTAL	NUMBER
<100				0
95-99	2		21	12
90-94	2		91	53
85-89	2		165	96
80-84	2		178	104
75-79	2		156	91
70-74	2		142	83
65-69			82	48
60-64			75	44
55-59			63	37
50-54			22	13
45-49			3	2
40-44				0
35-39				0
30-34				0
<30				0
TOTAL	7 3		1000	
NUMBER	0 4 2 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0		583

(con.)

Table 36. (Con.)

TEMPERATURE - RELATIVE HUMIDITY - WINDSPEED
PERCENTAGE FREQUENCY OF OCCURRENCE FOR SELECTED COMBINATIONS
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240217 HUNGRY HORSE RS 1958-1970

MONTH JUL

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94		13	15							
85-89		49	18							
80-84		8	36	18	3					
75-79			18	8	15	3				
70-74			8	13	8	3	3			
65-69				8		3		3		3
60-64						10		5	8	3
55-59						3	3	3		3
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL		69	95	46	26	21	5	10	8	8
NUMBER	0	27	37	18	10	8	2	4	3	3

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100	3									
95-99			15							
90-94			28	18						
85-89	3	54	77	10						
80-84			21	77	21					
75-79			18	39	31	10	10			
70-74			5	21	33	15	3			
65-69					10	13	3			
60-64					5	8	8		5	3
55-59							3	3		3
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	5	141	231	111	46	26	3	5	5	
NUMBER	2	55	90	43	18	10	1	2	2	0

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94		8	3							
85-89	5	13	13							
80-84	3	5	13	3						
75-79		3	3	5	3					
70-74			5	3		5				
65-69			5	3	8	3				
60-64				3	3	3				
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	8	28	41	15	13	10				
NUMBER	3	11	16	6	5	4	0	0	0	0

WIND SPEED 15-19 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89	3									
80-84		3		3						
75-79		3		3						
70-74			5							
65-69										
60-64										
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	3	5	5	5						
NUMBER	1	2	2	2	0	0	0	0	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79				3						
70-74		3								
65-69										
60-64										
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL		3		3						
NUMBER	0	1	0	1	0	0	0	0	0	0

TOTAL NUMBER

<100	3
95-99	15
90-94	85
85-89	244
80-84	211
75-79	172
70-74	131
65-69	59
60-64	62
55-59	18
50-54	0
45-49	0
40-44	0
35-39	0
30-34	0
<30	0
TOTAL	1000
NUMBER	389

STATION NUMBER 240217 HUNGRY HORSE RS 1958-1970

MONTH AUG

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100		3								
95-99		5								
90-94	3	33	5							
85-89		43	26	5						
80-84		28	36	3						
75-79		15	26	15	8					
70-74			15	8	15	10	8	3		
65-69			8	10	8	8		3		
60-64					8	8	5	5	10	
55-59					5		3	8	5	3
50-54							3	3	3	
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	3	128	115	41	43	26	18	20	18	3
NUMBER	1	50	45	16	17	10	7	8	7	1

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100	3									
95-99	8	10								
90-94		51	5							
85-89	8	36	26	3						
80-84	3	31	46	10						
75-79		10	36	20						
70-74		10	15	15	8					
65-69			5	20	10	8		3		
60-64				5	5	8	5		3	
55-59					5	8	3	5		
50-54						5		3	3	5
45-49									3	
40-44										
35-39										
30-34										
<30										
TOTAL	20	148	133	74	28	28	8	10	8	5
NUMBER	8	58	52	29	11	11	3	4	3	2

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94	3	10	3							
85-89	3	15	3							
80-84		13	10	5						
75-79								3		
70-74			5	3	3					
65-69				5					5	
60-64				5		10				
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	5	38	20	18	3	10	3	5		
NUMBER	2	15	8	7	1	4	1	2	0	0

WIND SPEED 15-19 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100		3								
95-99										
90-94										
85-89										
80-84		10	3							
75-79										
70-74										
65-69			3							
60-64				3						
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL		13	5	3						
NUMBER	0	5	2	1	0	0	0	0	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79										
70-74										
65-69										
60-64										
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL										
NUMBER	0	0	0	0	0	0	0	0	0	0

TOTAL NUMBER

<100	3
95-99	9
90-94	44
85-89	65
80-84	77
75-79	52
70-74	46
65-69	37
60-64	31
55-59	17
50-54	9
45-49	1
40-44	0
35-39	0
30-34	0
<30	0
TOTAL	1000
NUMBER	391

(con.)

Table 36. (Con.)

TEMPERATURE - RELATIVE HUMIDITY - WINDSPEED
PERCENTAGE FREQUENCY OF OCCURRENCE FOR SELECTED COMBINATIONS
GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240301 BELLY RIVER RS 1951-1970

MONTH JUL

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84			3	3	2		2			
75-79			7	16	7	5	2			
70-74				9	9	7	7			
65-69				5	7	5	2	5		
60-64					2	5	3	3	3	
55-59					2	3	2	10	9	
50-54								2	3	5
45-49									2	3
40-44										
35-39										
30-34										
<30										
TOTAL			10	33	28	26	17	21	17	9
NUMBER	0	0	6	19	16	15	10	12	10	5

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89				10						
80-84				24	16	2				
75-79			3	40	52	16				
70-74				14	35	28	12	3		
65-69				5	23	24	14	7		
60-64					2	7	12	10	5	
55-59						2	3	7	7	2
50-54								5	5	10
45-49									2	2
40-44									2	
35-39										
30-34										
<30										
TOTAL			3	94	127	78	42	33	21	14
NUMBER	0	2	54	73	45	24	19	12	8	1

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94			3	3						
85-89			5	3	2					
80-84			3	31	9					
75-79				42	36	5	3			
70-74			5	18	26	12	5			
65-69				9	28	12	5	2		
60-64					5	10	3	2	2	
55-59						7	5	9		3
50-54								2	2	2
45-49									2	
40-44									2	
35-39										
30-34										
<30										
TOTAL			17	99	106	47	23	14	7	5
NUMBER	0	10	57	61	27	13	8	4	3	0

WIND SPEED 15-19 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84			5	3						
75-79		3	3	5						
70-74		2	2	7	2					
65-69				7	3					
60-64				5	2	5		2		
55-59					5	3	3	2		
50-54						5	2	2		
45-49								2		
40-44										
35-39										
30-34										
<30										
TOTAL		5	10	28	12	14	5	7		
NUMBER	0	3	6	16	7	8	3	4	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84				2						
75-79	2	2	3		2					
70-74		2	2	2		2				
65-69					3					
60-64					3					
55-59					2					
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	2	3	7	2	10	2				
NUMBER	1	2	4	1	6	1	0	0	0	0

TOTAL	NUMBER
	0
	0
7	4
21	12
106	61
255	147
201	116
167	96
94	54
89	51
45	26
12	7
3	2
	0
	0
1000	
	576

STATION NUMBER 240301 BELLY RIVER RS 1951-1970

MONTH AUG

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		2		2						
80-84		3	5	3						
75-79		2	8	7	5	2				
70-74		2	3	7	12	8				
65-69				3	7	12	3	2	2	
60-64				3	5	5	3	10	3	
55-59						2		5	12	3
50-54					2	2		10	5	3
45-49								2	3	12
40-44										3
35-39										2
30-34										
<30										
TOTAL		8	17	25	30	30	7	28	25	23
NUMBER	0	5	10	15	18	18	4	17	15	14

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99	2									
90-94			7							
85-89			7	5	2					
80-84			13	32	8					
75-79			10	45	18	7				
70-74			3	20	38	18	3			
65-69				7	13	25	7	3		
60-64				3	5	13	18	3	3	3
55-59						3	10	10	2	2
50-54							5	5	2	3
45-49						2			5	2
40-44									2	
35-39										
30-34										
<30										
TOTAL	2	40	112	85	68	43	22	12	10	7
NUMBER	1	24	67	51	41	26	13	7	6	4

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		7	5							
80-84		8	18	3						
75-79		3	32	15	3					
70-74			33	20	5	3				
65-69			12	13	12	2				
60-64				10	18	10	2			
55-59					2	8	7	2		
50-54						5	8		2	
45-49							3	2		
40-44										2
35-39										
30-34										
<30										
TOTAL		18	100	62	40	28	20	3	2	2
NUMBER	0	11	60	37	24	17	12	2	1	1

WIND SPEED 15-19 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		2	2							
80-84		3	8							
75-79			15	2						
70-74		3	5	3	5					
65-69			5	5	3					
60-64				8	8	2				
55-59				2	3	2	3	3		
50-54					2	3		5		
45-49							3	2		
40-44										
35-39										
30-34										
<30										
TOTAL		8	33	20	22	7	7	10		
NUMBER	0	5	20	12	13	4	4	6	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89			2							
80-84				2						
75-79				3						
70-74				2	2	2				
65-69										
60-64					2					
55-59						3	2			
50-54								2		
45-49							3			
40-44										
35-39										
30-34										
<30										
TOTAL		2	7	3	5	5		2		
NUMBER	0	1	4	2	3	3	0	1	0	0

TOTAL	NUMBER
	0
2	1
7	4
83	20
109	65
177	106
199	119
134	80
140	84
87	52
63	38
42	25
7	4
2	1
	0
	0
1000	
	599

(con.)

Table 36. (Con.)

TEMPERATURE - RELATIVE HUMIDITY - WINDSPEED
PERCENTAGE FREQUENCY OF OCCURRENCE FOR SELECTED COMBINATIONS
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240303 ST MARY RS 1951-1970

MONTH JUL

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		2	10							
80-84	2	4	6	8		2				
75-79		2	8	4	6					
70-74		2		8	8	8				
65-69			2		8	4	6			2
60-64						4	2	2	4	
55-59						8	4	2	4	
50-54								4	6	
45-49									2	
40-44										
35-39										
30-34										
<30										
TOTAL	2	10	26	20	22	26	12	8	18	
NUMBER	1	5	13	10	11	13	6	4	9	0

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99	2	2								
90-94		10								
85-89		34	4	2						
80-84		10	42	26						
75-79		8	32	44	12	2				
70-74			18	36	30	6		2		
65-69			6	16	8	16	6			
60-64			2		14	8	4	2		
55-59					4			4	2	4
50-54						2	2	2	6	4
45-49										2
40-44										
35-39										
30-34										
<30										
TOTAL	2	65	105	125	69	34	12	10	8	10
NUMBER	1	32	52	62	34	17	6	5	4	5

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94		4	2							
85-89		14	12							
80-84	2	16	34	2	2					
75-79		12	44	16	4					
70-74		6	24	20	6	2				
65-69			6	12	10	4				
60-64				12	10	6	8		2	
55-59				2		6	14			
50-54				2	2					
45-49								2		
40-44										
35-39										
30-34										
<30										
TOTAL	2	52	123	67	34	18	22	2	2	
NUMBER	1	26	61	33	17	9	11	1	1	0

WIND SPEED 15-19 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89			2							
80-84	2	2	6		2					
75-79			4	2	4	2				
70-74		4	2	4		2				
65-69				4	4					
60-64				2	4	2				
55-59					4	4	4	2		
50-54							2			
45-49							2			
40-44									2	
35-39										
30-34										
<30										
TOTAL	2	6	14	12	18	10	8	2	2	
NUMBER	1	3	7	6	9	5	4	1	1	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100	2									
95-99										
90-94										
85-89										
80-84										
75-79		2								
70-74			2	2	2					
65-69					2					
60-64						2	2			
55-59										
50-54								2		
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL	2	2	2	2	6	2	2			
NUMBER	1	1	1	1	3	1	1	0	0	0

TOTAL

TEMP. DEG F	TOTAL	NUMBER
<100	2	1
95-99	4	2
90-94	16	8
85-89	81	40
80-84	169	84
75-79	210	104
70-74	196	97
65-69	117	58
60-64	89	44
55-59	73	36
50-54	34	17
45-49	6	3
40-44	4	2
35-39		0
30-34		0
<30		0
TOTAL	1000	
NUMBER		496

STATION NUMBER 240303 ST MARY RS 1951-1970

MONTH AUG

WIND SPEED 0-4 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99	2									
90-94										
85-89		6								
80-84		6	10	2						
75-79			2	8	2					
70-74			2	8	6	2				
65-69			6	6	4	8	2	4		
60-64					6	4		2	6	
55-59					2	2	2		4	2
50-54								6	10	2
45-49									6	2
40-44										2
35-39										
30-34										
<30										
TOTAL	2	11	19	23	19	15	4	11	25	8
NUMBER	1	6	10	12	10	8	2	6	13	4

WIND SPEED 5-9 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99		2								
90-94	2	2								
85-89		21	10							
80-84		19	38	23						
75-79	2	8	42	29	4	2				
70-74			13	27	13					
65-69			4	17	11	10				
60-64			4	4	10	8	8	2		
55-59			2		2	6	2	4	2	
50-54						4	6	4	6	
45-49						2	2	2	4	2
40-44								2		
35-39									2	
30-34										
<30										
TOTAL	4	52	113	99	40	31	17	13	11	4
NUMBER	2	27	59	52	21	16	9	7	6	2

WIND SPEED 10-14 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94		8								
85-89		15	10							
80-84		15	34	8						
75-79		15	46	13	4					
70-74			27	31	10	2				
65-69			8	17	8	8				
60-64				4	13	19	6	4		
55-59				2	4	2	2	2	4	
50-54					2	4	8			
45-49							4		2	
40-44										
35-39										
30-34										
<30										
TOTAL		54	124	75	40	34	19	6	6	
NUMBER	0	28	65	39	21	18	10	3	3	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP. DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89			2	2						
80-84		2	6							
75-79	2	2	4	6	2	2				
70-74			11	4						
65-69			4	2	15					
60-64					10	6				
55-59				2	4	4	2			
50-54					2	2	2			
45-49						2	2	2		
40-44										
35-39										
30-34										
<30										
TOTAL	2	4	27	15	33	15	6	2		
NUMBER	1	2	14	8	17	8	3	1	0	0

TOTAL

TEMP. DEG F	TOTAL	NUMBER
<100		0
95-99	4	2
90-94	11	6
85-89	65	34
80-84	164	86
75-79	195	102
70-74	159	83
65-69	132	69
60-64	120	63
55-59	57	30
50-54	55	29
45-49	31	16
40-44	4	2
35-39	2	1
30-34		0
<30		0
TOTAL	1000	
NUMBER		523

(con.)

Table 36. (Con.)

T E M P E R A T U R E - R E L A T I V E H U M I D I T Y - W I N D S P E E D
PERCENTAGE FREQUENCY OF OCCURRENCE FOR SELECTED COMBINATIONS
-GIVEN TO TENTHS PERCENT, DECIMAL POINT OMITTED

STATION NUMBER 240206 DESERT MTN 1951-1970

MONTH JUL

WIND SPEED 0-4 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		2	2							
80-84		2	2	3						
75-79		3	26	10	2	2				
70-74		3	27	41	15					
65-69			14	19	19	7	5			
60-64			2	14	27	17	5	5		
55-59				2		10	7			2
50-54						2	9	5	2	3
45-49					2	3		9	10	5
40-44										12
35-39										
30-34										2
<30										
TOTAL		10	72	89	65	41	26	19	12	24
NUMBER	0	6	42	52	38	24	15	11	7	14

WIND SPEED 5-9 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89			2							
80-84			2	17	3					
75-79		2	10	58	20	7				
70-74			10	41	55	14	2			
65-69			3	19	39	27	10			
60-64				9	29	19	19	7		
55-59				3	5	12	26	5	3	2
50-54						2	7	12	5	3
45-49						2	2	5		5
40-44									3	2
35-39										2
30-34										2
<30										
TOTAL		2	27	147	152	82	65	29	12	14
NUMBER	0	1	16	86	89	48	38	17	7	8

WIND SPEED 10-14 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79			3	9	2					
70-74			2	12	3	2				
65-69			3	2	7	2				
60-64				3	3	2				
55-59					2	2	2			
50-54							3		3	2
45-49							2		2	2
40-44									3	
35-39										
30-34										
<30										
TOTAL			9	26	17	7	7		9	3
NUMBER	0	0	5	15	10	4	4	0	5	2

WIND SPEED 15-19 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79		2	2							
70-74			3							
65-69										
60-64										
55-59					2					
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL		2	5		2					
NUMBER	0	1	3	0	1	0	0	0	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79										
70-74										
65-69										
60-64						2				
55-59					2				2	
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL					2	2			2	
NUMBER	0	0	0	0	1	1	0	0	1	0

TEMP, DEG F	TOTAL	NUMBER
<100		0
95-99		0
90-94		0
85-89	5	3
80-84	29	17
75-79	157	92
70-74	230	135
65-69	175	103
60-64	162	95
55-59	89	52
50-54	60	35
45-49	58	34
40-44	29	17
35-39	3	2
30-34	3	2
<30		0
TOTAL	1000	
NUMBER		587

STATION NUMBER 240206 DESERT MTN 1951-1970

MONTH AUG

WIND SPEED 0-4 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89		2								
80-84		3	5	2						
75-79		7	12	3						
70-74		2	27	15	5	2				
65-69			10	27	15	14				
60-64		2	2	15	24	7	5	2	2	
55-59				3	9	9	5	3	2	
50-54				2	3	3	7	9	7	12
45-49					2	5	5	2	9	7
40-44								5	3	9
35-39										3
30-34										
<30										
TOTAL		15	56	74	58	39	22	21	22	31
NUMBER	0	9	33	43	34	23	13	12	13	18

WIND SPEED 5-9 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94			2							
85-89			5							
80-84			21	9	3					
75-79			14	44	7	2				
70-74			19	50	27	7				
65-69		2	5	44	32	21	5	2		
60-64				14	39	14	14	3	2	
55-59					17	14	14	2	2	3
50-54				2		7	9	5	5	2
45-49								7	3	5
40-44									9	3
35-39										2
30-34										
<30										
TOTAL		2	65	162	126	63	41	19	21	15
NUMBER	0	1	38	95	74	37	24	11	12	9

WIND SPEED 10-14 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84		10	2							
75-79		2	10							
70-74			12	3						
65-69		3	12	7	3	2				
60-64			2	2	3					
55-59				2				3		
50-54						2		3	2	
45-49							2	2	2	2
40-44										3
35-39										3
30-34										
<30										
TOTAL		15	38	14	7	3	2	9	3	9
NUMBER	0	9	22	8	4	2	1	5	2	5

WIND SPEED 15-19 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79										
70-74				2						
65-69										
60-64					2	2				
55-59										
50-54										
45-49										
40-44								2		
35-39										
30-34										
<30										
TOTAL				2	2	2		2		
NUMBER	0	0	0	1	1	1	0	1	0	0

WIND SPEED GREATER/EQUAL 20 MPH

TEMP, DEG F	RELATIVE HUMIDITY 1 TO 10	11 TO 20	21 TO 30	31 TO 40	41 TO 50	51 TO 60	61 TO 70	71 TO 80	81 TO 90	91 TO 100
<100										
95-99										
90-94										
85-89										
80-84										
75-79										
70-74										
65-69										
60-64										
55-59										
50-54										
45-49										
40-44										
35-39										
30-34										
<30										
TOTAL										
NUMBER	0	0	0	0	0	0	0	0	0	0

TEMP, DEG F	TOTAL	NUMBER
<100		0
95-99		0
90-94		1
85-89	2	4
80-84	7	32
75-79	55	59
70-74	101	100
65-69	171	120
60-64	205	90
55-59	154	54
50-54	92	48
45-49	82	38
40-44	65	29
35-39	50	10
30-34	17	0
<30		0
TOTAL	1000	
NUMBER		585

Finklin, Arnold I. A climatic handbook for Glacier National Park—with data for Waterton Lakes National Park. General Technical Report INT-204. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 124 p.

A climatic description of the Glacier-Waterton Lakes Park area; mainly covers Glacier. Contains numerous tables, graphs, and maps showing the year-round pattern of climatic elements and 10-day details during fire season. Data analysis includes frequency distributions in addition to average values. Examines relationship of averages to topography, weather correlations between stations, persistence of weather, and climatic trends during this century.

KEYWORDS: climate, mountain climatology, fire-weather, fire management, Glacier National Park

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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**Intermountain
Research Station**

General Technical
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Appraising Fuels and Flammability in Western Aspen: A Prescribed Fire Guide

James K. Brown
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NOV 25 1986
DOCUMENTS



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RESEARCH SUMMARY

This report explains how to appraise fuels and flammability in aspen forests as a means for choosing good opportunities for prescribed burning and for determining the environmental conditions favorable for a successful burn. The appraisal process is based on a study of physical fuel properties and vegetation occurring in southeastern Idaho and western Wyoming. Fuels were classified into five types: **aspen/shrub**, **aspen/tall forb**, **aspen/low forb**, **mixed/shrub**, and **mixed/forb**, based on overstory composition, shrub coverage, and quantity of herbaceous vegetation. The fuel types are illustrated with color photographs accompanied by information on fuel loadings, vegetational characteristics, adjective fire behavior ratings, and ratings for probability of a successful burn. To aid in writing fire prescriptions the report includes tables of predicted fireline intensity and rate of spread as a function of fine fuel moisture content, vegetation curing, windspeed, and slope.

Grazing reduced fire behavior potential by 80 to 90 percent of ungrazed conditions. The authors discuss how fire behavior is affected by downed woody fuel accumulations, leaf fall, small conifers, canopy closure, and rodent activity. Adjective ratings of fire intensity, rate of spread, torching, and resistance to contol incorporate the influence of downed woody fuel accumulations and conifers. The **aspen/shrub** type is the most flammable, followed by **mixed/shrub**. The **aspen/tall forb** is intermediate in flammabilty and has about one-half of the fire intensity potential of **aspen/shrub**. The **aspen/low forb** and **mixed/forb** types are least flammable. Probabilities of successful burning range from high to low because fuels and flammability varied substantially among fuel types and among certain stands within fuel types.

The guide provides an example of how to determine a range of windspeeds, fine fuel moisture contents, and curing levels for writing fire prescriptions. Moisture contents and curing trends of grasses and forbs are described. Forb moisture contents remained high until late summer, then dropped substantially over a 3-week period, regardless of rainfall. The guide includes a visual method of estimating percentage of curing based on the finding that green and transition-stage moisture contents are similar and differ significantly from those of the cured stage. Details of fuel model development and fire behavior prediction are provided.

August 1986

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Appraising Fuels and Flammability in Western Aspen: A Prescribed Fire Guide

James K. Brown
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INTRODUCTION

Aspen (*Populus tremuloides*) is widely distributed throughout North America. It occupies approximately 7 million acres in the Western United States (Green and Van Hooser 1983). Aspen forests provide wood products but are especially valued as wildlife habitat, for grazing by domestic livestock, for sources of water, and for esthetics and recreation (DeByle 1978). Fire has played an integral part in the development of aspen forests. The purpose of this report is to assist in planning and conducting prescribed fires to maintain aspen forests.

Aspen exists as both a climax and seral species but is seral on the majority of sites, eventually to be replaced by conifers (Mueggler 1976). On stable aspen sites, frequent fires can maintain a grass-forb community, with aspen suckers confined to the shrub layer (Crane 1982). Infrequent fires produce varying effects on stand structure. Low-intensity fires cause thinning and encourage an all-aged condition. High-intensity fires result in new even-aged stands.

Seral aspen is gradually replaced by conifers. This may take 200 to 400 years or more (Bartos and others 1983), depending on the potential for establishment and growth of conifers. If succession continues without fire, aspen will eventually be crowded out. This successional process reduces forage production from approximately 700 lb/acre to 200 lb/acre (Kranz and Linder 1973; Reynolds 1969), reduces water yields from about 20 area inches to 16 inches (Jaynes 1978; Gifford and others 1983, 1984), and diminishes vegetation diversity and habitat for many species of wildlife (DeByle 1985).

Prescribed fire may offer an economically and environmentally acceptable means of rejuvenating aspen. Prescribed fire is particularly appropriate in remote areas and areas where cutting is not a feasible tool for regenerating aspen. Fire, when properly applied, also stimulates temporary increases in production of grasses, forbs, and shrubs. It creates a diversity of cover types and tree sizes on the landscape.

Prescribed fire has not been commonly used to regenerate aspen in the Western United States partly because the aspen forest is regarded as difficult to burn. Concerns for fire control have limited burning in aspen during late summer when flammability of adjoining forest types is typically greatest. In autumn, when flammability of the forest has lessened, burning opportunities in aspen are frequently restricted to only a few days and in some years none at all.

Prescribed fire in aspen, however, can be successfully used. Fuels and flammability vary considerably within the aspen and mixed aspen-conifer overstory types. In planning prescribed fire in aspen, it is particularly important to choose locations that are sufficiently flammable to meet fire objectives. The best time of year to burn in aspen varies by the type of understory vegetation. Choosing the proper time to burn is critical to achieving successful prescribed fires.

This paper presents a method for appraising fuels and flammability in aspen forests to assist in choosing good opportunities for using prescribed fire and to help determine the proper conditions for burning. Also, a method is described for evaluating the curing of vegetation to determine when herbaceous fuels are ready to burn.

METHOD DEVELOPMENT

Fuel Types

Fuels were classified into five types that differed substantially in vegetation and potential fire behavior (table 1). The classification of understories was keyed to amount of shrubs and productivity of herbaceous vegetation. Tall forbs dominated the forb component of high productivity herbaceous types and low forbs dominated the forb component of low productivity types. Aspen dominated the overstory in three types: **aspen/shrub**, **aspen/tall forb**, and **aspen/low forb**. Productivity and fuel loadings of herbaceous vegetation were greater in the tall forb than in the low forb group. Conifers dominated the overstory in two types: **mixed/shrub** and **mixed/forb**. Herbaceous vegetation under the mixed overstories was considerably less varied than under aspen; thus only one forb group was used for classifying flammability. Conifers commonly encountered in the overstory include subalpine fir (*Abies lasiocarpa*), Douglas-fir (*Pseudotsuga menziesii*), and lodgepole pine (*Pinus contorta*).

The fuel type classification was initially formed by grouping community types on the Bridger-Teton National Forest (Youngblood and Mueggler 1981) and the Targhee and Caribou National Forests (Mueggler and Campbell 1982) based on expected differences in flammability. Community types are aggregations of similar plant communities based upon existing vegetation regardless of successional status. Existing understory vegetation significantly influences flammability in aspen forests; thus, flammability is related to community types.

Table 1.—A vegetation classification of aspen fuels and flammability

Characteristics	Vegetation - fuel types				
	Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
Overstory species occupying 50 percent or more of canopy	Aspen	Aspen	Aspen	Conifers	Conifers
Shrub coverage, percent	Greater than 30	Less than 30	Less than 30	Greater than 30	Less than 30
Community type understory indicator species that may be present	*Prunus* *Bromus* *Amelanchier* *Shepherdia* *Symphoricarpos* *Artemisia* *Juniperus* *Pachistima*	*Ranunculus* *Heracleum* *Ligusticum* *Spiraea* *Calamagrostis* *Rudbeckia* *Wyethia*	*Prunus* *Berberis* *Arnica* *Astragalus* *Thalictrum* *Geranium* *Poa*	*Ligusticum* *Shepherdia* *Spiraea* *Amelanchier* *Symphoricarpos*	*Pedicularis* *Berberis* *Arnica* *Calamagrostis* *Thalictrum*

Live and dead fuels were then sampled in 33 stands from southeastern Idaho and western Wyoming, representing the initial fuel types. Stands were selected to provide a diversity of community types. An area that appeared to represent a designated community type was located in each stand and photographed. Fuel loadings and fuel bed bulk densities were sampled within each photographic scene.

Fire behavior was predicted using these fuel data as well as a range of windspeeds and fuel moisture contents as input to Rothermel's (1972) fire-spread model. The fuel and fire behavior data were ranked from high to low. Overlap among fuel types and meaningful breaks in the rankings were evaluated and adjustments made in the initial classification. Primarily, tall shrub and low shrub groups, initially recognized, were consolidated because they overlapped considerably in fuels and flammability.

Although this fuel type classification is based on community types found in southeastern Idaho and western Wyoming, community type descriptions for other areas such as the Bear Lodge Mountains and Black Hills (Severson and Thilenius 1976) could probably be interpreted to fit this classification. This fuel type classification and appraisal of flammability should be applicable to other areas if the structure of understory vegetation is similar. The classification criteria, which distinguish differences in flammability, are keyed to amount of shrubs, grasses, and forbs. Understory species are important only as they influence kinds and amounts of vegetation.

Fire Behavior

Fire behavior was evaluated in three ways:

1. Probability of achieving sustained fire spread with sufficient heat to kill aspen.
2. Ratings of fire behavior potential.
3. Fireline intensity and rate of spread predicted using mathematical models.

Probability of Sustained Spread.—The probability of successfully using prescribed fire was subjectively rated for the aspen fuel types and for the effects of grazing and downed woody fuel accumulations on flammability.

A successful fire was defined as having sustained spread and sufficient heat to kill aspen up to 12 inches d.b.h. Probabilities of attaining success were defined on the basis of judgment as:

Low — Fine fuels are insufficient to support fire spread. Windspeed and fine fuel moistures are rarely adequate to sustain spread.

Moderate — Fine fuels mostly from herbaceous vegetation; loadings marginal for sustained spread; fuel continuity is broken and compactness open. Windspeed and fine fuel moisture meet burning prescription every few years.

High — Loading of downed dead woody and herbaceous fuel adequate for sustained fire spread; good fine fuel continuity. Windspeed and fine fuel moistures come into prescription almost annually.

Fire Behavior Potential.—Photographs of each plot were rated in terms of potential fire behavior for an "average bad" fire weather situation. Six fire specialists experienced in prescribed fire and fuel appraisal rated the photographs and accompanying fuel loading data. The assumed weather was: temperature of 80 to 90 °F, relative humidity of 15 to 20 percent, windspeed of 10 to 15 mi/h at 20-ft level, and last measurable rain some 4 weeks ago. Five expressions of fire behavior were rated: rate of spread, fire intensity, torching, resistance to control, and overall fire potential. This approach to rating fire potential was first introduced by Hornby (1936). Although subjective, it has been used extensively in fuel appraisal. The valuable aspect of these ratings is that facets of fire behavior that are not easily evaluated analytically can be mentally evaluated and related to years of experience.

The adjective ratings "nil," "low," "medium," "high," and "extreme" are defined as follows based on Fischer's (1981) photo guides for appraising fuels:

Intensity:

Nil—fire cannot sustain itself.

Low—cool fire; very little hot spotting required for control.

Medium—fire will burn hot in places; aggressive hot spotting with hand tools likely to be successful.

High—too hot for sustained direct attack with hand tools; aerial tankers or large ground tanker required to cool fire front.

Extreme—direct ground attack not possible; air or ground tanker attack likely to be ineffective.

Rate-of-Spread:

Nil—fire cannot sustain itself.

Low—spread will be slow and discontinuous.

Medium—uniform spread possible but can be stopped by aggressive ground attack with hand tools.

High—spread will be rapid; indirect attack on fire front may be required for control.

Extreme—spread will be explosive; little chance of control until weather changes.

Torching:

Nil—no chance of torching.

Low—occasional tree may torch-out.

Medium—pole-sized understory trees likely to torch-out.

High—most of understory and occasional overstory trees likely to torch-out.

Extreme—entire stand likely to torch-out.

Resistance to Control Action:

Nil—no physical impediments to line building and holding.

Low—occasional tough spots but not enough to cause serious line building and holding problems.

Medium—hand line construction will be difficult and slow but dozers can operate without serious problems.

High—slow work for dozers, very difficult for hand crews; hand line holding will be difficult.

Extreme—neither dozers nor hand crews can effectively build and hold line.

Overall Fire Potential:

Nil—fire will not sustain itself.

Low—fire can be easily controlled by several smokechasers with hand tools.

Medium—aggressive crew-sized (6-10 persons) initial attack required for successful control.

High—aggressive crew-sized (25 persons) initial attack with substantial reinforcement required for successful control; 10 percent chance that control action will fail.

Extreme—90 percent chance that control action will fail.

Mathematical Model.—Rothermel's (1972) fire-spread model provided the basis for predicting rate of spread and fireline intensity using program FIREMOD (Albini 1976). Fuel models, which are input values to the mathematical fire model, were constructed for each aspen fuel type based on average fuel loadings and fuel bed bulk densities determined from sampling. Some adjustments to the fuel models were necessary to maintain realistic differences in fire behavior among the aspen fuel types.

Live Fuel Moisture

Moisture content of perennial grasses and forbs was sampled weekly throughout two growing seasons in western Wyoming to investigate prediction of live fuel moisture from easily determined indexes. Grass and forb moisture contents were correlated with the National Fire-Danger Rating System model of live fuel moistures (Burgan 1979) and with the Keetch-Byram Drought Index (Keetch and Byram 1968).

The moisture content of recognizable curing stages was also sampled to develop a field procedure for estimating curing levels that would be useful in deciding when to burn. Curing refers to the change in moisture content of vegetation as it matures through the growing season into dormancy. Three stages of curing, identifiable by color, are commonly recognized in evaluating fire danger (Burgan 1979): green, transition, and cured.

Results of live fuel moisture sampling as well as details about fuel model development and fire behavior prediction are described in following sections.

FIRE PRESCRIPTION GUIDE

This section provides information for designing fire prescriptions and deciding when live vegetation will burn according to the prescription. As a first step, set objectives for the fire and identify constraints in using it. Next, consult technical aids that describe fuels, summarize weather, and forecast fire behavior and fire effects to help write the fire prescription. This process, described in more detail by Brown (1985), produces prescriptions of when and how to burn specific areas. Additional discussion on planning and evaluating prescribed fires is furnished by Fischer (1978) and Martin and Dell (1978).

The following topics are discussed in a logical sequence for writing and executing a fire prescription in aspen stands:

1. Set objectives
2. Consult technical aids
   a. Select fuel types
   b. Appraise fire behavior potentials
3. Determine the fire prescription
4. Determine when curing of vegetation meets the prescription.

Setting Objectives

Both land management and fire objectives should be clearly defined. First, set the land management objectives. These objectives deal with resource values and are derived from the goals of an organization or landowner. They should focus on the composition, amount, and arrangement of vegetation over time, which are fundamental to describing land management objectives.

Fire is an appropriate means to improve range, wildlife, and watershed resource values of the aspen ecosystem. In this case, the land management goal should be to maintain the aspen cover type, preferably with a mix of age/size classes. If fire is used to reduce slash and stimulate understory production in conjunction with

harvesting, the land management objective might be to develop another commercial stand of aspen. If so, achieving some minimum number of aspen stems per acre might be an objective. When the land management objective is to maintain the aspen cover type, however, number of stems per acre is probably of minor concern because range, wildlife, and watershed values can be enhanced over a wide range of aspen stand densities. An appropriate objective in this situation may be to maintain aspen at or above some minimal canopy coverage; or to maintain aspen at or above some minimal proportion of the overstory composition.

Density of aspen suckers can vary widely following fire. If flammability varies considerably within burn units, a mosaic of burned and unburned patches may result. But if fire of adequate intensity reaches most areas this mosaic of burned and unburned areas should successfully maintain aspen in a diversity of age classes.

Once land management objectives are established, objectives of the fire can be defined. These should state what fire itself can directly accomplish. Basically this involves specifying the vegetation to be killed and the organic matter to be consumed. To achieve effective suckering, the objective should be to kill all or most (probably at least 80 percent) of the aspen in a stand. Sucker production is most prolific when all or most of the aspen stems are killed. Within each tree killed, the balance between growth-inhibiting and growth-promoting hormones is altered which, in turn, promotes suckering (Schier 1981). Full sunlight reaching the forest floor after killing the overstory enhances both production and survival of suckers. Sucker production after less than half of the overstory aspen is killed is apt to be ineffective (Horton and Hopkins 1965). In some mixed stands, it may be unnecessary to kill patches of pure aspen if surrounding conifers can be removed by fire or harvesting. Regardless of whether fire carries through patches of aspen, reduction of conifer cover may be the primary objective for treating mixed conifer-aspen stands.

Constraints on achieving the fire objectives must also be defined. Constraints affecting the fire prescription deal primarily with controlling the fire and managing smoke. Getting the fire to spread can be considered a constraint, too.

Fuel Type Appraisal

To appraise fire behavior, select a fuel type that best fits a prospective burn area. If necessary, select more than one type to represent a mosaic of aspen types. Consult the following descriptions and photographs to assist in selecting fuel types. The photographs serve as examples of vegetation and fuels that typify the fuel types. The photographs do not represent all community types or floristic arrangements that occur across the landscape but are a sample of them. An idea of variability in fuels and vegetation within fuel types can be visualized by comparing scenes that represent the same fuel type.

The key features that distinguish fuel types are overstory composition, shrub coverage, and quantity of herbaceous vegetation (table 1). Species composition of the understory relates to shrub coverages and herb quantities. Small woody plants such as *Spiraea betulifolia* and *Berberis repens* are included with herbaceous species in this fuel classification. Even though they can occur with high coverage, their contribution to fuel loading is minor compared to other shrubs. Where small woody plants are abundant, they should be considered as part of the herbaceous component for determining classification.

Each photograph is accompanied by information on fuel loading, vegetation characteristics, and adjective ratings of fire behavior, and probability of successful burn.

The fuel loading components include:

Herbaceous - live and dead nonwoody vegetation, primarily grasses and forbs.

Shrub - foliage and all live and dead standing stemwood of woody plants (except for some small woody species).

Litter - freshly cast leaves, bark flakes, and miscellaneous vegetative parts and matted grass that are expected to burn during passage of a flaming fire front. This is a liberal interpretation of the 01 horizon or L layer of the forest floor because some partially decomposed aspen leaves were included in the samples.

Downed woody material - dead twigs, branches, and stemwood by diameter classes in inches that lie in or above the litter.

Fines - the sum of fuel less than one-fourth inch in thickness, which includes herbaceous vegetation, shrub foliage, shrub stemwood less than one-fourth inch diameter, litter, and downed woody material less than one-fourth inch diameter.

This information is specific to each scene and is intended to help appraise flammability and the likelihood of successfully using prescribed fire. Use photographs to help classify areas of interest based on the kind and amount of understory vegetation.

ASPEN/SHRUB

Aspen dominates the overstory. It occupies at least 50 percent of the canopy, and typically 80 to 100 percent of it. Shrub coverage and biomass may vary considerably, but coverage must be 30 percent or more. Low shrub situations, however, such as those dominated by *Symphoricarpos* or *Pachistima* spp., fit the flammability characteristics of the shrub type more realistically when shrub cover exceeds 40 to 50 percent. Other shrubs commonly found in this fuel type include *Artemisia tridentata, Prunus virginiana, Shepherdia canadensis, Amelanchier alnifolia,* and *Ceanothus velutinus.*



Fuel class: Aspen/shrub — Stand No. 2

Community type: *Populus tremuloides/Artemisia tridentata*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	1,000	0.112
b. Shrub	1,860	.209
c. Litter	1,540	.172
Downed woody		
d. 0 to ¼	210	.023
e. ¼ to 3	7,640	.856
f. 3+	13,430	1.505
Subtotals		
Fines	3,980	.445
D. woody 0-3	7,850	.879

VEGETATION CHARACTERISTICS	
Shrub cover, %	31
Basal area, ft²/acre	
Aspen	36
Conifer	0

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Nil
Resistance to control	Low
Overall	Medium
Probability of a successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Little Bear Creek
Photo date	August 1982



Fuel class: Aspen/shrub Stand No. 15

Community type: *Populus tremuloides/Pachistima myrsinites*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	740	0.084
b. Shrub	4,530	.508
c. Litter	2,510	.281
Downed woody		
d. 0 to ¼	720	.081
e. ¼ to 3	7,450	.835
f. 3+	34,460	3.863
Subtotals		
Fines	7,150	.802
D. woody 0-3	8,170	.916

VEGETATION CHARACTERISTICS	
Shrub cover, %	43
Basal area, ft²/acre	
Aspen	102
Conifer	0

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Low
Resistance	
to control	Medium
Overall	Medium
Probability of a successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Allred Campground
Photo date	August 1982



Fuel class: Aspen/shrub — Stand No. 20

Community type: *Populus tremuloides/Prunus virginiana*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	390	0.044
b. Shrub	4,000	.448
c. Litter	2,350	.263
Downed woody		
d. 0 to ¼	430	.048
e. ¼ to 3	3,150	.353
f. 3+	6,320	.708
Subtotals		
Fines	5,270	.591
D. woody 0-3	3,580	.401

VEGETATION CHARACTERISTICS	
Shrub cover, %	56
Basal area, ft²/acre	
Aspen	47
Conifer	0

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Nil
Resistance to control	Medium
Overall	Medium
Probability of a successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Little Cottonwood Creek
Photo date	September 1982



Fuel class: Aspen/shrub — Stand No. 23

Community type: *Populus tremuloides/Shepherdia canadensis*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	810	0.091
b. Shrub	2,200	.247
c. Litter	2,810	.315
Downed woody		
d. 0 to ¼	260	.029
e. ¼ to 3	5,230	.586
f. 3+	5,520	.619
Subtotals		
Fines	5,020	.563
D. woody 0-3	5,490	.615

VEGETATION CHARACTERISTICS	
Shrub cover, %	32
Basal area, ft²/acre	
Aspen	62
Conifer	7

FIRE RATING	
Intensity	Medium
Rate of spread	Med-High
Torching	Low-Med
Resistance	
to control	Medium
Overall	Med-High
Probability of a	
successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Goosewing Creek
Photo date	September 1982

ASPEN/TALL FORB

Aspen dominates the overstory. It occupies at least 50 percent of the canopy, and typically 80 to 100 percent of it. Shrubs are sparse. Shrub coverage is less than 30 percent and frequently less than 10 percent. Productivity of herbaceous vegetation typically exceeds 1,000 lb/acre/yr. Tall forbs and grasses commonly found in this fuel type include *Calamagrostis rubescens, Bromus* sp., *Elymus glaucus, Balsamorhiza macrophylla, Ligusticum filicinum, Lupinus argenteus, Osmorhiza occidentalis, Rudbeckia occidentalis,* and *Wyethia amplexicaulis.*

Stand No. 19 illustrates an understory dominated by a small woody plant, *Spiraea betulifolia,* but still classified in the **aspen/tall forb** fuel type. Stands No. 9 and 31 show heavily grazed situations.



Fuel class: Aspen/tall forb — Stand No. 5

Community type: *Populus tremuloides/Rudbeckia occidentalis*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	2,020	0.226
b. Shrub	0	0
c. Litter	1,760	.197
Downed woody		
d. 0 to ¼	40	.004
e. ¼ to 3	7,100	.796
f. 3+	60,300	6.759
Subtotals		
Fines	3,820	.427
D. woody 0-3	7,140	.800

VEGETATION CHARACTERISTICS	
Shrub cover, %	0
Basal area, ft²/acre	
Aspen	82
Conifer	0

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Nil
Resistance to control	Low
Overall	Low
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Little Bear Creek
Photo date	August 1982



Fuel class: Aspen/tall forb — Stand No. 9

Community type: *Populus tremuloides/Rudbeckia occidentalis*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	450	0.050
b. Shrub	0	0
c. Litter	2,880	.323
Downed woody		
d. 0 to ¼	120	.014
e. ¼ to 3	2,810	.315
f. 3+	70,180	7.866
Subtotals		
Fines	3,460	.387
D. woody 0-3	2,930	.329

VEGETATION CHARACTERISTICS	
Shrub cover, %	0
Basal area, ft²/acre	
Aspen	102
Conifer	17

FIRE RATING	
Intensity	Nil
Rate of spread	Nil
Torching	Nil
Resistance to control	Low
Overall	Nil
Probability of a successful burn	Low

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Stepp Creek
Photo date	September 1983



Fuel class: Aspen/tall forb — Stand No. 10

Community type: *Populus tremuloides/Wyethia amplexicaulis*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	1,450	0.162
b. Shrub	30	.003
c. Litter	2,060	.231
Downed woody		
d. 0 to ¼	110	.012
e. ¼ to 3	4,590	.514
f. 3+	7,200	.807
Subtotals		
Fines	3,650	.409
D. woody 0-3	4,700	.526

VEGETATION CHARACTERISTICS	
Shrub cover, %	6
Basal area, ft²/acre	
Aspen	63
Conifer	3

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Low
Resistance to control	Nil
Overall	Low
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Bluejay Creek
Photo date	September 1982



Fuel class: Aspen/tall forb — Stand No. 19

Community type: *Populus tremuloides/Spiraea betulifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	230	0.025
b. Shrub	980	.110
c. Litter	2,600	.292
Downed woody		
d. 0 to ¼	540	.060
e. ¼ to 3	4,690	.526
f. 3+	7,950	.891
Subtotals		
Fines	4,320	.484
D. woody 0-3	5,230	.586

VEGETATION CHARACTERISTICS	
Shrub cover, %	58
Basal area, ft²/acre	
Aspen	62
Conifer	2

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Low
Resistance to control	Low
Overall	Low
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Sheep Gulch
Photo date	September 1983



Fuel class: Aspen/tall forb — Stand No. 21

Community type: *Populus tremuloides/Ligusticum filicinum*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	1,060	0.119
b. Shrub	40	.004
c. Litter	1,130	.127
Downed woody		
d. 0 to ¼	180	.020
e. ¼ to 3	16,030	1.797
f. 3+	59,510	6.670
Subtotals		
Fines	2,400	.270
D. woody 0-3	16,210	1.816

VEGETATION CHARACTERISTICS	
Shrub cover, %	3
Basal area, ft²/acre	
Aspen	203
Conifer	0

FIRE RATING	
Intensity	Low-Med
Rate of spread	Low
Torching	Low
Resistance to control	Medium
Overall	Low-Med
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Little Dry Cottonwood Creek
Photo date	September 1983



Fuel class: Aspen/tall forb — Stand No. 25

Community type: *Populus tremuloides/Calamagrostis rubescens*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	1,030	0.116
b. Shrub	440	.049
c. Litter	2,240	.251
Downed woody		
d. 0 to ¼	270	.030
e. ¼ to 3	1,240	.139
f. 3+	0	0
Subtotals		
Fines	3,890	.435
D. woody 0-3	1,510	.169

VEGETATION CHARACTERISTICS	
Shrub cover, %	21
Basal area, ft²/acre	
Aspen	107
Conifer	0

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Nil
Resistance to control	Low
Overall	Low
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Jackson
Drainage	Horsetail Creek
Photo date	September 1982



Fuel class: Aspen/tall forb — Stand No. 31

Community type: *Populus tremuloides/Rudbeckia occidentalis*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	790	0.088
b. Shrub	0	0
c. Litter	1,150	.129
Downed woody		
d. 0 to ¼	160	.018
e. ¼ to 3	9,100	1.020
f. 3+	11,710	1.312
Subtotals		
Fines	2,100	.235
D. woody 0-3	9,260	1.038

VEGETATION CHARACTERISTICS	
Shrub cover, %	0
Basal area, ft²/acre	
Aspen	63
Conifer	0

FIRE RATING	
Intensity	Nil
Rate of spread	Nil
Torching	Nil
Resistance	
to control	Nil
Overall	Nil
Probability of a	
successful burn	Low

STAND LOCATION	
National Forest	Caribou
Ranger District	Soda Springs
Drainage	Diamond Creek
Photo date	September 1983

ASPEN/LOW FORB

Aspen dominates the overstory. It occupies at least 50 percent of the canopy, and typically 80 to 100 percent of it. Shrubs are sparse. Shrub coverage is less than 30 percent and frequently less than 10 percent. Productivity of herbaceous vegetation is low, usually less than 900 lb/acre/yr. Plants commonly encountered in this fuel type include *Poa* sp., *Arnica cordifolia, Geranium* sp., and *Berberis repens.*



Fuel class: Aspen/low forb — Stand No. 7

Community type: *Populus tremuloides/Berberis repens*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	280	0.031
b. Shrub	330	.037
c. Litter	2,000	.225
Downed woody		
d. 0 to ¼	370	.042
e. ¼ to 3	4,550	.510
f. 3+	2,370	.266
Subtotals		
Fines	2,980	.335
D. woody 0-3	4,920	.552

VEGETATION CHARACTERISTICS	
Shrub cover, %	18
Basal area, ft²/acre	
Aspen	140
Conifer	0

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Nil
Resistance to control	Low
Overall	Low
Probability of a successful burn	Low

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Fontenelle Creek
Photo date	September 1983



Fuel class: Aspen/low forb — Stand No. 8

Community type: *Populus tremuloides/Arnica cordifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	180	0.02
b. Shrub	0	0
c. Litter	2,740	.307
Downed woody		
d. 0 to ¼	420	.047
e. ¼ to 3	5,680	.636
f. 3+	5,840	.654
Subtotals		
Fines	3,330	.374
D. woody 0-3	6,100	.683

VEGETATION CHARACTERISTICS	
Shrub cover, %	0
Basal area, ft²/acre	
Aspen	143
Conifer	0

FIRE RATING	
Intensity	Nil
Rate of spread	Nil
Torching	Nil
Resistance to control	Nil
Overall	Nil
Probability of a successful burn	Low

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Little Fall Creek
Photo date	September 1983

MIXED/SHRUB

Conifers comprise more than 50 percent of the overstory, but aspen is still a substantial component. Shrub coverage comprised of tall or low shrubs is 30 percent or more.



Fuel class: Mixed/shrub — Stand No. 17

Community type: *Populus tremuloides-Pseudotsuga menziesii/Spiraea betulifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	80	0.010
b. Shrub	2,480	.278
c. Litter	2,040	.228
Downed woody		
d 0 to ¼	1,250	.140
e. ¼ to 3	7,130	.800
f. 3+	1,280	.143
Subtotals		
Fines	4,850	.543
D. woody 0-3	8,380	.940

VEGETATION CHARACTERISTICS	
Shrub cover, %	56
Basal area, ft²/acre	
Aspen	101
Conifer	70

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Medium
Resistance	
to control	Medium
Overall	Medium
Probability of a	
successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Greys River
Drainage	Greys River
Photo date	August 1982



Fuel class: Mixed/shrub Stand No. 29

Community type: *Populus tremuloides-Pseudotsuga menziesii/Spiraea betulifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	90	0.011
b. Shrub	3,670	.411
c. Litter	1,920	.215
Downed woody		
d. 0 to ¼	630	.070
e. ¼ to 3	4,920	.551
f. 3+	3,400	.381
Subtotals		
Fines	5,020	.563
D. woody 0-3	5,550	.622

VEGETATION CHARACTERISTICS	
Shrub cover, %	70
Basal area, ft²/acre	
Aspen	46
Conifer	37

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Medium
Resistance to control	Medium
Overall	Medium
Probability of a successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Greys River
Drainage	Greys River
Photo date	September 1983

MIXED/FORBS

Conifers comprise more than 50 percent of the overstory, but aspen is still a substantial component. Shrub coverage is less than 30 percent. Herbaceous vegetation is often poorly developed. Productivity is low, usually less than 800 lb/acre/yr. Stands No. 1 and 29 illustrate heavy accumulations of downed woody material, which raises the flammability ratings of these and similar stands.



Fuel class: Mixed/forb — Stand No. 1

Community type: *Populus tremuloides-Abies lasiocarpa/Arnica cordifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	50	0.005
b. Shrub	80	.008
c. Litter	3,660	.411
Downed woody		
d. 0 to ¼	2,070	.232
e. ¼ to 3	12,400	1.390
f. 3+	52,440	5.877
Subtotals		
Fines	5,860	.656
D. woody 0-3	14,470	1.622

VEGETATION CHARACTERISTICS	
Shrub cover, %	4
Basal area, ft²/acre	
Aspen	37
Conifer	160

FIRE RATING	
Intensity	High
Rate of spread	Medium
Torching	High
Resistance to control	High
Overall	High
Probability of a successful burn	High

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Bluejay Creek
Photo date	August 1982



Fuel class: Mixed/forb Stand No. 3

Community type: *Populus tremuloides-Abies lasiocarpa/Arnica cordifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	260	0.030
b. Shrub	100	.011
c. Litter	2,310	.259
Downed woody		
d. 0 to ¼	260	.030
e. ¼ to 3	3,830	.429
f. 3+	8,620	.966
Subtotals		
Fines	2,930	.329
D. woody 0-3	4,090	.459

VEGETATION CHARACTERISTICS	
Shrub cover, %	14
Basal area, ft²/acre	
Aspen	79
Conifer	42

FIRE RATING	
Intensity	Low
Rate of spread	Low
Torching	Low
Resistance to control	Nil
Overall	Low
Probability of a successful burn	Low

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Kemmerer
Drainage	Little Bear Creek
Photo date	August 1982



Fuel class: Mixed/forb Stand No. 16

Community type: *Populus tremuloides-Abies lasiocarpa/Arnica cordifolia*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	10	0.001
b. Shrub	480	.054
c. Litter	2,560	.287
Downed woody		
d. 0 to ¼	260	.029
e. ¼ to 3	5,010	.561
f. 3+	9,490	1.064
Subtotals		
Fines	3,020	.339
D. woody 0-3	5,270	.590

VEGETATION CHARACTERISTICS	
Shrub cover, %	7
Basal area, ft²/acre	
Aspen	118
Conifer	63

FIRE RATING	
Intensity	Medium
Rate of spread	Low
Torching	Medium
Resistance to control	Low
Overall	Low-Med
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Bridger-Teton
Ranger District	Greys River
Drainage	Smith Fork
Photo date	August 1982



Fuel class: Mixed/forb Stand No. 28

Community type: *Populus tremuloides-Pinus contorta/Calamagrostis rubescens*

FUEL LOADINGS	*Lb/acre*	*kg/m²*
a. Herbaceous	550	0.062
b. Shrub	1,400	.157
c. Litter	1,260	.141
Downed woody		
d. 0 to ¼	400	.045
e. ¼ to 3	10,120	1.134
f. 3+	31,040	3.479
Subtotals		
Fines	3,150	.354
D. woody 0-3	10,520	1.179

VEGETATION CHARACTERISTICS	
Shrub cover, %	19
Basal area, ft²/acre	
Aspen	59
Conifer	21

FIRE RATING	
Intensity	Medium
Rate of spread	Medium
Torching	Low
Resistance to control	Medium
Overall	Medium
Probability of a successful burn	Moderate

STAND LOCATION	
National Forest	Caribou
Ranger District	Soda Springs
Drainage	Slug Creek
Photo date	September 1983

FUEL CHARACTERISTICS

A summary of data from the sampled stands (table 2) illustrates several important differences and similarities among the fuel classes:

1. Shrubs contributed significantly to fine fuel loadings, as shown by comparing fine fuel loadings and shrub coverages.
2. Fine fuel loadings differed substantially between the shrub and forb understory types and between the **aspen/tall forb** and **aspen/low forb** types.
3. Herbaceous vegetation in the **aspen/tall forb** class averaged two to four times greater than in the other classes.
4. Litter loadings differed greatly among individual stands within types, but the average difference among types was small and not meaningful.
5. Loadings of downed woody fuel 0 to 1 inch and 0 to 3 inches in diameter also varied substantially from stand to stand. The mixed types appear to have slightly more downed woody fuel than the other types, which is understandable because conifer crowns shed more small dead twigs and branches than aspen. However, considering the variation among stands, the differences among types appear insignificant. This emphasizes a need to appraise downed woody fuels on an individual stand basis.
6. Differences in dead fuel loading between the **aspen/shrub** and **mixed/shrub** types are small. Nevertheless, these types should be regarded separately because conifers in the mixed type are likely to torch, thus creating a more intense fire. Similarly, the **aspen/low forb** and **mixed/low forb** classes should remain distinct, even though differences in dead fuel loadings are reasonably small.

Predicted fireline intensities for typical late summer conditions (fig. 1) reflect the differences among fuel types due to fine fuel loadings, particularly the high herbaceous component (table 2). In general, the **aspen/shrub** type is the most flammable, followed by **mixed/shrub**. The **aspen/tall forb** type has about one-half the fire intensity potential of **aspen/shrub**. The **aspen/low forb** and **mixed/forb** types are the least flammable. The relative differences among fuel types remain about the same over a range of windspeeds, live fuel moisture contents, and curing percentages normally experienced during late summer and early fall.

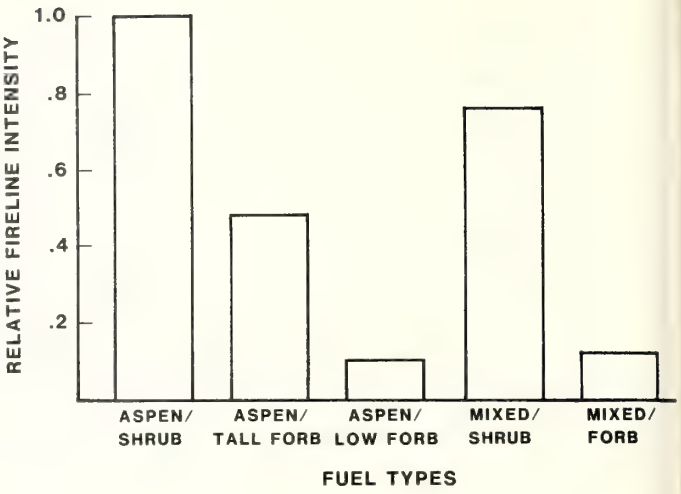


Figure 1.—Fireline intensity calculated under the assumption that 50 percent of the herbaceous vegetation is cured, fine fuel moisture content is 8 percent, slope is 0 percent, and midflame windspeed is 4 mi/h. The intensities are relative, being expressed as a fraction of the intensity for **aspen/shrub**.

Table 2.—Average fuel loadings and shrub cover from sampled stands representing the aspen fuel types. Ranges in values are in parentheses

Fuel	Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
			Lb/acre		
Herbaceous	670 (230 to 1,000)	1,330 (1,030 to 2,020)	300 (180 to 460)	90 (80 to 90)	290 (10 to 550)
Shrubs[1]	3,170 (980 to 6,150)	110 (0 to 440)	260 (0 to 630)	3,040 (2,480 to 3,610)	630 (100 to 1,350)
Litter	1,810 (420 to 2,810)	1,600 (790 to 2,240)	1,350 (170 to 2,740)	1,980 (1,920 to 2,040)	1,680 (740 to 2,560)
Fines[2]	6,140 (4,030 to 9,390)	3,170 (1,970 to 3,990)	2,430 (1,640 to 3,330)	6,050 (5,850 to 6,250)	3,070 (2,150 to 3,560)
Downed woody 0 to 1 inch	2,440 (710 to 4,220)	1,080 (620 to 1,440)	2,600 (1,460 to 3,690)	4,240 (3,400 to 5,080)	2,710 (1,440 to 3,900)
Downed woody 0 to 3 inch	7,020 (3,580 to 12,510)	7,340 (1,510 to 16,210)	5,720 (3,290 to 7,600)	6,970 (5,550 to 8,390)	7,810 (4,090 to 12,250)
			Percent		
Shrub cover	40 (30 - 60)	10 (0 - 20)	10 (0 - 30)	60 (60 - 70)	20 (10 - 30)

[1]Shrubs include foliage and stemwood.
[2]Fines include live and dead herbaceous plants and shrubs, litter, and 0- to ¼-inch downed woody fuel.

Appraising Flammability

Flammability is altered by many factors, some of which are difficult to evaluate analytically. The approaches presented here to appraising flammability involve expert opinion and mathematical prediction of fire behavior. Each approach has advantages and disadvantages. The appraisals differ in form and are useful in different ways.

PROBABILITY OF SUCCESSFUL BURNING

The probability-of-success ratings in table 3 reflect the influence of grazing and quantities of downed woody fuel.

The grazing and fuel conditions are as follows:

Ungrazed - very light or no grazing

Grazed - moderately or heavily grazed

Light downed woody fuel - average or less than average accumulations

Heavy downed woody fuel - much greater than average accumulations

In planning prescribed fires, categories rated as poor success suggest situations that should be avoided. Other means of disturbance, particularly cutting, should be used if possible. Efforts to use prescribed fire in aspen should focus on situations having moderate to high probabilities of success. The **aspen/shrub** and **mixed/shrub** fuel types provide the best opportunities. The **aspen/tall forb** and **mixed/forb** fuel types provide marginal opportunities. Careful appraisal of individual sites is essential in these fuel types to determine whether a successful prescription can be written.

FIRE POTENTIAL RATINGS

The fire intensity and rate-of-spread ratings determined for each sampled plot were summarized for the fuel types and combinations of grazing intensity and downed woody fuel accumulations (table 4).

General trends from table 4 are:

1. The **mixed/forb** class has higher fire potential than the **aspen/low forb** class due to differences in downed woody fuel loadings and torching potentials. The differences between these two classes are greater in table 4 than indicated by the fire behavior predictions.
2. Grazing reduces fire intensity and rate of spread by at least one rating level.
3. Heavy fuel loadings result in increased intensities except where substantial grazing is expected.
4. Heavy fuel loadings increase rate of spread in stands with mixed overstories, but not aspen overstories.

Table 3.—Probabilities of successfully applying prescribed fire in aspen forests according to fuel types and the influence of grazing and quantities of downed woody material

		Fuel types				
Grazing	Woody fuel	Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
Ungrazed	Light	high	moderate	low	high	moderate
Ungrazed	Heavy	high	moderate	low	high	high
Grazed	Light	moderate	low	low	moderate	low
Grazed	Heavy	high	low	low	high	moderate

Table 4.—Fire intensity and rate of spread adjective ratings according to fuel types, grazing intensity, and downed woody fuel quantities. The first rating is for intensity and the second for rate of spread. H, M, L, N mean high, moderate, low, and nil, respectively

		Fuel types				
Grazing	Woody fuel	Aspen/ shrub	Aspen/ tall forb	Aspen/ low forb	Mixed/ shrub	Mixed/ forb
Ungrazed	Light	M-M	L-L	N-N	M-M	L-L
Ungrazed	Heavy	H-M	M-L	L-L	H-H	M-M
Grazed	Light	L-L	N-N	N-N	L-L	N-N
Grazed	Heavy	M-L	N-N	N-N	M-L	L-L

FIRE BEHAVIOR PREDICTIONS

Fireline intensity (table 5) and rate-of-spread (table 6) values were determined for the aspen fuel types using the BEHAVE fire behavior prediction and fuel modeling system (described in detail later). Tables 5 and 6 show variation in fire behavior by fuel types, midflame windspeed, fine dead fuel moisture content, and level of curing. They are based on a live fuel moisture content of 150 percent for herbaceous vegetation and 55 to 85 percent for live woody plants. These moisture contents represent late summer and early fall conditions. Tables 5 and 6, adjusted for 20-ft wind and slope, can be used to judge the likelihood of achieving successful prescribed fires and to determine a range in level of curing, fine fuel moisture content, windspeed, and slope for preparing fire prescriptions.

The fine fuel moisture contents in tables 5 and 6 reflect the range in moistures over which prescribed burning may be possible. The 1- and 10-hour timelag fuel categories are the standard size classes of 0 to ¼ inch and ¼ to 1 inch used in fire-danger rating and fire behavior prediction (Rothermel 1983). In these tables, the 10-hour fuel moisture contents were set slightly higher than the 1-hour moisture contents because this reflects typical field conditions. Fire behavior can be readily interpolated between fuel moisture levels in the tables.

Table 5. (Con.)—**Aspen/tall forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Btu/ft/s*												
30 percent cured														
4	6	2	5	10	17	25	35	46	75	105	140	175	220	265
8	10	2	4	7	12	18	26	34	50	75	100	130	160	195
12	14	2	3	6	11	16	22	29	46	65	90	110	140	170
16	18	2	3	6	10	15	21	28	44	60	85	105	130	160
50 percent cured														
4	6	3	7	13	23	34	48	65	100	140	190	240	300	360
8	10	2	5	9	16	24	34	44	70	100	130	170	210	255
12	14	2	4	8	14	20	28	38	60	85	110	145	180	215
16	18	2	3	7	11	17	24	32	50	70	95	120	150	180
70 percent cured														
4	6	5	9	19	32	48	65	90	140	195	260	335	415	505
8	10	3	6	13	21	32	45	60	95	135	180	225	280	340
12	14	3	5	10	18	27	38	50	80	110	150	190	235	285
16	18	2	4	9	15	22	31	41	65	90	120	155	195	235
90 percent cured														
4	6	7	14	27	46	70	100	130	200	290	385	495	610	740
8	10	4	8	17	29	44	60	80	130	180	244	310	385	465
12	14	4	7	14	24	36	50	65	105	150	200	255	315	380
16	18	3	6	12	20	29	41	55	85	120	160	205	255	310

(con.)

Table 5.—Fireline intensity, **Aspen/shrub** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Btu/ft/s*												
30 percent cured														
4	6	4	9	19	32	48	65	85	135	190	250	315	385	460
8	10	3	7	14	24	36	50	65	100	140	185	235	285	345
12	14	3	6	12	21	31	43	55	85	120	160	205	250	300
16	18	2	5	11	18	27	37	49	75	105	140	175	215	260
50 percent cured														
4	6	6	14	28	47	70	95	125	195	275	360	455	560	675
8	10	4	10	20	34	50	70	90	140	195	260	330	405	485
12	14	4	8	17	28	42	60	75	120	165	220	275	340	410
16	18	3	7	14	24	35	49	65	100	140	180	230	285	340
70 percent cured														
4	6	9	19	40	70	100	140	180	280	395	525	665	815	980
8	10	6	14	28	47	70	100	130	195	275	365	465	570	685
12	14	5	11	23	40	60	80	105	165	230	305	390	475	575
16	18	4	9	19	32	48	65	85	135	190	250	315	390	465
90 percent cured														
4	6	13	28	60	100	150	205	270	415	585	770	980	1,205	1,450
8	10	9	19	40	65	100	140	180	280	395	525	665	815	980
12	14	7	16	33	55	85	115	150	230	325	430	550	675	810
16	18	6	13	27	45	65	95	120	190	265	350	445	550	660

(con.)

Table 5. (Con.)—**Aspen/low forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Btu/ft/s*												
		30 percent cured												
4	6	1	2	3	5	7	9	11	16	22	28	34	41	48
8	10	1	1	2	3	5	6	8	11	15	19	24	29	34
12	14	0	1	2	3	4	5	6	10	13	16	20	24	29
16	18	0	1	2	2	3	4	5	8	11	14	17	20	24
		50 percent cured												
4	6	1	2	4	6	8	10	13	19	25	32	40	48	55
8	10	1	1	2	4	5	7	9	13	17	22	27	32	38
12	14	1	1	2	3	4	6	7	11	14	18	23	27	32
16	18	0	1	2	3	4	5	6	9	12	15	19	22	26
		70 percent cured												
4	6	1	2	4	6	9	12	15	22	30	38	47	55	65
8	10	1	2	3	4	6	8	10	15	20	25	31	37	44
12	14	1	1	2	4	5	7	8	12	16	21	25	31	36
16	18	1	1	2	3	4	5	7	10	13	17	21	25	30
		90 percent cured												
4	6	1	3	5	8	12	15	19	28	38	48	60	70	85
8	10	1	2	3	5	7	10	12	18	24	30	37	44	50
12	14	1	1	3	4	6	8	10	14	19	24	30	35	42
16	18	1	1	2	3	5	6	8	11	15	19	24	29	34

(con.)

Table 5. (Con.)—**Mixed/shrub** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Btu/ft/s*												
		30 percent cured												
4	6	4	8	16	26	38	50	65	100	140	185	230	280	330
8	10	3	6	12	19	28	39	50	75	105	135	170	205	245
12	14	2	5	10	16	24	33	42	65	90	115	145	175	210
16	18	2	4	8	14	20	27	35	55	75	95	120	145	175
		50 percent cured												
4	6	5	11	22	36	55	70	90	140	190	250	310	380	450
8	10	4	8	16	26	38	50	65	100	135	180	225	270	325
12	14	3	7	13	22	32	43	55	85	115	150	190	230	275
16	18	2	6	11	18	26	35	46	70	95	125	155	185	220
		70 percent cured												
4	6	7	15	29	48	70	95	125	185	255	330	415	510	605
8	10	5	10	20	35	49	65	85	130	180	235	290	355	420
12	14	4	9	17	28	41	55	70	110	150	195	245	300	355
16	18	3	7	14	23	36	46	60	90	120	160	200	245	290
		90 percent cured												
4	6	9	20	40	65	95	130	165	255	350	460	575	700	835
8	10	6	13	26	43	65	85	110	165	230	300	380	465	550
12	14	5	11	22	36	50	70	90	140	190	250	315	385	455
16	18	4	9	18	29	42	60	75	115	155	205	255	315	375

(con.)

Table 5. (Con.)—**Mixed/forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Btu/ft/s*												
		30 percent cured												
4	6	1	2	4	6	8	11	14	20	27	34	42	50	60
8	10	1	1	3	4	6	7	9	14	18	23	29	34	40
12	14	1	1	2	3	5	6	8	12	15	20	24	29	34
16	18	1	1	2	3	4	5	6	10	13	16	20	24	28
		50 percent cured												
4	6	1	2	4	7	10	13	16	23	31	39	48	60	70
8	10	1	2	3	4	6	8	10	15	21	26	32	38	45
12	14	1	1	2	4	5	7	9	13	17	22	27	32	38
16	18	1	1	2	3	4	6	7	11	14	18	22	27	31
		70 percent cured												
4	6	1	3	5	8	11	15	19	27	36	46	55	70	80
8	10	1	2	3	5	7	10	12	17	23	30	37	44	50
12	14	1	2	3	4	6	8	10	14	19	24	30	36	42
16	18	1	1	2	4	5	6	8	12	16	20	27	30	35
		90 percent cured												
4	6	2	4	6	10	14	18	23	33	44	55	70	85	95
8	10	1	2	4	6	8	11	14	20	27	35	43	50	60
12	14	1	2	3	5	7	9	11	16	22	28	34	41	48
16	18	1	1	2	4	6	7	9	13	18	22	28	33	39

Table 6.—Rate of spread, **Aspen/shrub** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Ft/min*												
		30 percent cured												
4	6	1	1	3	5	7	9	12	19	26	35	44	54	65
8	10	1	1	2	4	6	8	10	16	23	30	38	46	56
12	14	<1	1	2	4	5	7	10	15	21	28	35	43	51
16	18	<1	1	2	3	5	7	9	14	19	25	32	39	47
		50 percent cured												
4	6	1	2	4	6	9	13	17	26	36	48	60	74	89
8	10	1	1	3	5	8	11	14	21	30	40	50	62	74
12	14	1	1	3	5	7	10	13	19	27	36	45	56	67
16	18	1	1	2	4	6	9	11	17	24	32	41	50	60
		70 percent cured												
4	6	1	2	5	9	13	18	23	35	50	66	84	103	124
8	10	1	2	4	7	10	14	19	29	41	54	68	84	100
12	14	1	2	4	6	9	13	17	26	36	48	60	74	89
16	18	1	2	3	5	8	11	15	22	32	42	53	65	78
		90 percent cured												
4	6	2	3	7	12	18	24	32	49	69	92	117	144	173
8	10	1	3	5	9	14	19	25	39	55	72	92	113	136
12	14	1	2	5	8	12	17	22	34	48	63	80	99	118
16	18	1	2	4	7	10	15	19	29	41	55	70	86	103

(con.)

Table 6. (Con.)—**Aspen/tall forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
-- *Pct* --		---------- *Ft/min* ----------												
		30 percent cured												
4	6	<1	1	2	3	4	6	8	12	17	23	30	37	45
8	10	<1	1	1	2	4	5	7	10	15	20	25	31	38
12	14	<1	1	1	2	3	5	6	10	14	18	23	29	35
16	18	<1	1	1	2	3	4	6	9	13	18	22	28	34
		50 percent cured												
4	6	1	1	2	4	6	8	10	16	23	31	39	48	59
8	10	<1	1	2	3	5	6	8	13	19	25	32	40	48
12	14	<1	1	2	3	4	6	8	12	17	23	29	36	43
16	18	<1	1	1	2	4	5	7	11	15	20	26	32	39
		70 percent cured												
4	6	1	1	3	5	8	11	14	22	31	42	53	66	80
8	10	1	1	2	4	6	8	11	18	25	33	43	52	64
12	14	1	1	2	4	5	8	10	16	22	30	38	47	57
16	18	<1	1	2	3	5	7	9	14	20	26	33	41	50
		90 percent cured												
4	6	1	2	4	7	11	16	21	33	46	62	79	98	119
8	10	1	2	3	6	9	12	16	25	35	47	60	74	90
12	14	1	1	3	5	7	10	14	21	30	40	52	64	77
16	18	1	1	2	4	6	9	12	18	26	35	45	55	67

(con.)

Table 6. (Con.)—**Aspen/low forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
-- *Pct* --		---------- *Ft/min* ----------												
		30 percent cured												
4	6	<1	<1	1	1	2	2	3	4	5	7	8	10	11
8	10	<1	<1	1	1	1	2	2	3	4	5	7	8	9
12	14	<1	<1	1	1	1	2	2	3	4	5	6	7	8
16	18	<1	<1	<1	1	1	1	2	2	3	4	5	6	7
		50 percent cured												
4	6	<1	<1	1	1	2	2	3	4	6	7	9	11	13
8	10	<1	<1	1	1	1	2	2	4	5	6	7	9	11
12	14	<1	<1	1	1	1	2	2	3	4	5	7	8	9
16	18	<1	<1	1	1	1	2	2	3	4	5	6	7	8
		70 percent cured												
4	6	<1	1	1	2	2	3	4	5	7	9	11	14	16
8	10	<1	<1	1	1	2	2	3	4	6	7	9	10	12
12	14	<1	<1	1	1	1	2	2	4	5	6	8	9	11
16	18	<1	<1	1	1	1	2	2	3	4	5	7	8	9
		90 percent cured												
4	6	<1	1	1	2	3	4	5	7	9	12	14	17	20
8	10	<1	1	1	1	2	3	3	5	7	9	11	13	15
12	14	<1	<1	1	1	2	2	3	4	6	7	9	11	13
16	18	<1	<1	1	1	2	2	3	4	5	6	8	9	12

(con.)

Table 6. (Con.)—**Mixed/shrub** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Ft/min*												
30 percent cured														
4	6	<1	1	2	3	5	7	9	13	18	24	30	36	43
8	10	<1	1	2	3	4	6	7	11	16	20	25	31	37
12	14	<1	1	2	3	4	5	7	10	14	18	23	28	33
16	18	<1	1	1	2	4	5	6	9	13	17	21	25	30
50 percent cured														
4	6	1	1	3	5	7	9	12	17	24	31	39	47	56
8	10	1	1	2	4	5	7	10	14	20	26	32	39	47
12	14	<1	1	2	3	5	7	9	13	18	23	29	35	42
16	18	<1	1	2	3	4	6	8	11	16	21	26	31	37
70 percent cured														
4	6	1	2	4	6	9	12	15	23	31	41	51	63	74
8	10	1	1	3	5	7	9	12	18	25	33	42	51	60
12	14	1	1	3	4	6	8	11	16	23	29	37	45	53
16	18	1	1	2	4	5	7	10	14	20	26	32	39	47
90 percent cured														
4	6	1	2	5	8	11	15	20	30	42	54	68	83	99
8	10	1	2	4	6	9	12	15	23	32	42	52	64	76
12	14	1	2	3	5	8	10	13	20	28	36	46	56	66
16	18	1	1	3	4	7	9	12	17	24	32	40	48	58

(con.)

Table 6. (Con.)—**Mixed/forb** fuel type

Fuel moisture		Midflame windspeed (mi/h)												
1-h	10-h	0	1	2	3	4	5	6	8	10	12	14	16	18
Pct		*Ft/min*												
30 percent cured														
4	6	<1	<1	1	1	2	2	3	4	5	7	9	10	12
8	10	<1	<1	1	1	1	2	2	3	4	6	7	8	10
12	14	<1	<1	1	1	1	2	2	3	4	5	6	7	9
16	18	<1	<1	<1	1	1	1	2	3	3	4	5	7	8
50 percent cured														
4	6	<1	<1	1	1	2	3	3	5	6	8	10	12	14
8	10	<1	<1	1	1	2	2	3	4	5	6	8	9	11
12	14	<1	<1	1	1	1	2	2	3	4	6	7	8	10
16	18	<1	<1	1	1	1	2	2	3	4	5	6	7	9
70 percent cured														
4	6	<1	1	1	2	2	3	4	6	7	10	12	14	16
8	10	<1	<1	1	1	2	2	3	4	6	7	9	11	13
12	14	<1	<1	1	1	2	2	3	4	5	6	8	9	11
16	18	<1	<1	1	1	1	2	2	3	4	5	7	8	10
90 percent cured														
4	6	<1	1	1	2	3	4	5	7	9	12	15	17	20
8	10	<1	<1	1	2	2	3	4	5	7	9	11	13	15
12	14	<1	<1	1	1	2	2	3	4	6	7	9	11	13
16	18	<1	<1	1	1	2	2	3	4	5	6	8	9	11

Windspeeds are for midflame heights. They can be related to winds 20 ft above vegetation in order to use weather forecasts and prepare fire prescriptions. Table 7, condensed from Rothermel (1983), shows the correspondence between windspeeds at midflame and 20-ft heights. Fuels in aspen stands can be exposed, partially sheltered, or fully sheltered depending on canopy closure and topography. Usually aspen stands are partially sheltered or fully sheltered. Winds 20 ft above vegetation are frequently 2 to 4 times greater than at midflame height. Whether windspeeds will be adequate to sustain fire spread can be a major obstacle in prescribed burning of aspen. Stands topographically protected from prevailing winds can be especially troublesome to burn.

The effects of slope on fireline intensity and rate of spread are included in a new artificial windspeed called effective windspeed (fig. 2). Topographic slope has the same effect as increased windspeed in the fire behavior predictions presented here. To determine an effective windspeed that corresponds to a given wind and slope in figure 2, extend a vertical line from a chosen slope percentage until it intersects a midflame windspeed line of interest. Then extend a line horizontally to meet the y axis where an effective windspeed is read. For example, a 2-mi/h windspeed on a 60 percent slope is effectively the same as a 4.6-mi/h windspeed on the flat. Use effective windspeed by entering it at the top of tables 5 and 6.

A reverse process can be followed in figure 2 to determine a midflame windspeed that corresponds to an effective windspeed at a given slope. This process can help in writing fire prescriptions. Minimum windspeeds for fire prescriptions that correspond to minimally acceptable fireline intensities in table 5 can be determined from effective windspeeds that incorporate both wind and slope.

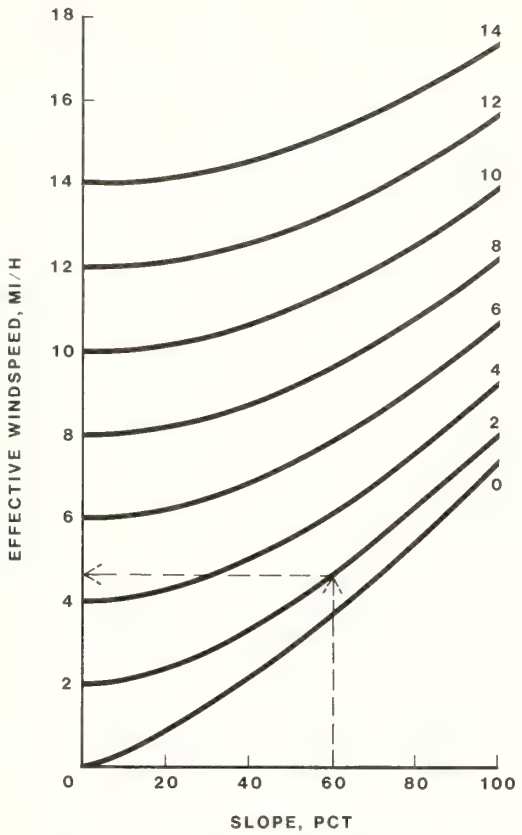


Figure 2.—Effective windspeed at midflame height for all of the aspen fuel models depends upon topographic slope. For example (shown by the dashed arrows), at a slope of 60 percent an actual midflame windspeed of 2 mi/h corresponds to an effective windspeed of 4.6 mi/h.

Table 7.—Wind adjustment table shows approximate midflame windspeeds for 20-ft windspeeds at the top of column[1]

Fuel exposure	20-ft windspeed (mi/h)						
	0-3	4-7	8-12	13-18	19-24	25-31	32-38
	Midflame windspeed (mi/h)						
EXPOSED FUELS Fuels exposed directly to wind—no overstory or sparse overstory; overstory without foliage; near clearings; on high ridges	1	2	4	6	9	11	14
PARTIALLY SHELTERED FUELS Fuels beneath patchy overstory canopies; beneath full canopies with wind blowing directly at the slope	1	2	3	5	7	8	11
FULLY SHELTERED FUELS							
Fuels beneath overstories on flat or gentle slopes -Open stands	0	1	2	3	4	6	7
Fuels beneath overstories on flat or gentle slopes -Dense stands	0	1	1	2	2	3	4

[1]Windspeed at 20 ft multiplied by wind adjustment factors gives midflame windspeed. Wind adjustment factors from Rothermel (1983) used to generate this table were exposed fuels, 0.4; partially sheltered fuels, 0.3; fully sheltered open stands, 0.2; fully sheltered dense stands, 0.1.

Table 8.—Tabulation of curing levels, fine fuel moisture contents, and midflame windspeeds that provide at least the minimum fireline intensity of 28 Btu/ft/s as an illustration of steps 2b, 2c, and 3

Curing	Step 2b			Step 2c	Step 3
	Fine fuel moisture (1-h)	Midflame windspeed	Fireline intensity	Minimum windspeed (20 ft)	Maximum windspeed (20 ft)
	Percent	*Mi/h*	*Btu/ft/s*	*Mi/h*	
50	4	2	28	0 - 5	20
50	8	3	34	6 - 11	25
50	12	3	28	6 - 11	25
50	16	4	35	12 - 17	25
70	4	2	40	0 - 5	20
70	8	2	28	0 - 5	25
70	12	3	40	6 - 11	25
70	16	3	32	6 - 11	25

Table 8, which was derived from figure 2 and table 7, simplifies the task of relating midflame windspeed to 20-ft windspeed and adjusting for slope by incorporating these relationships in one table. An example of determining a fire prescription using table 8 and a minimally acceptable fireline intensity is illustrated later.

Wind is assumed to blow directly at the slope and not from the sides for the intensity and spread rate values in tables 5 and 6. When winds blow across the slope, the intensities and spread rates are reduced depending on the angle of the wind across the slope. For winds blowing at a 45° angle to the slope, intensities and spread rates will only be reduced about 5 percent or less. This reduction is too small to be of practical significance and can be ignored. Winds blowing at 90° to the slope (directly across the slope) reduce fireline intensities and rates of spread from 5 to 25 percent, depending upon slope percentage and midflame windspeed (fig. 3). As a rule-of-thumb, reduce fireline intensity and rate of spread by 20 percent for winds blowing across slope. This small reduction may be significant when dealing with marginal intensities for successful prescribed fire. If predicted fireline intensities are not marginal for success, the adjustments can be disregarded.

Use the 30 percent curing level in tables 5 and 6 for curing less than 30 percent. Curing of vegetation from completely green to about 30 percent cured has little effect on fire behavior. As curing continues beyond 30 percent, however, fire behavior increases significantly for the **aspen/shrub, aspen/tall forb**, and **mixed/forb** fuel types (fig. 4).

Fireline intensity in table 5 is the amount of heat released per second through a 1-ft wide swath of the fire front. Flame length, which is the distance between the tip of the flame and the ground midway in the zone of active flaming, relates directly to fireline intensity. Because flame length can be more easily visualized than fireline intensity, the relationship between the two variables is shown in figure 5.

More resolution in fire behavior prediction than provided here can be obtained using the BEHAVE computer programs (Burgan and Rothermel 1984; Andrews 1986). Suggestions for using BEHAVE with the aspen fuel types are discussed in the appendix.

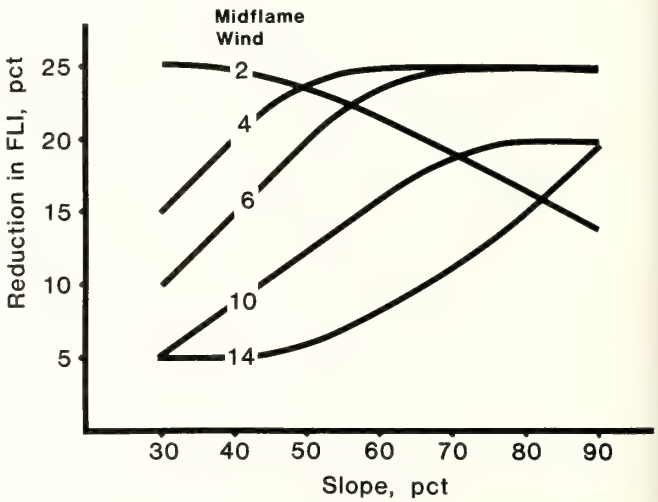


Figure 3.—Reduction in fireline intensity (FLI) due to winds blowing directly across the slope (90° to the slope), according to slope percentage and midflame windspeed.

LIMITATIONS

The fire behavior predictions must be interpreted with an awareness of limitations. The predictions are based on the assumption that fuels are uniform and continuous. The predictions apply to the propagating front of fire spreading in surface fuels. Crowning and spotting are not predicted by the model.

Perhaps the biggest limitation to planning prescribed fires in aspen forests is that a fire often will not spread even though the mathematical model predicts fire behavior. The values in tables 5 and 6 must be viewed as expected intensities and rates of spread providing fires will spread. Determining whether fire will sustain spread requires experience and judgment. Experience gathered in a study of fire in aspen (Brown and DeByle 1982) indicates that flame lengths should exceed 1 to 1.5 ft before sustained spread is possible. To accomplish this, herbaceous vegetation in the **aspen/shrub** and **aspen/tall forb** types should be at least 50 percent cured.

Although the fire behavior predictions and ratings provided here are based on sound technical knowledge,

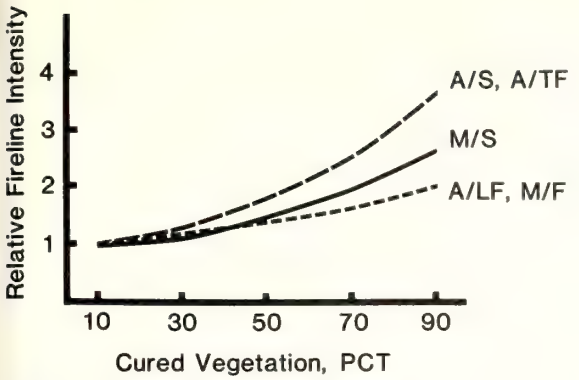


Figure 4.—Relative fireline intensities influenced by percentage of herbaceous vegetation that is cured. Relative intensities were calculated for each fuel type as the intensity at any curing level divided by the intensity at 0 percent curing. Fuel types are abbreviated as **aspen/shrub** - A/S, **aspen/tall forb** - A/TF, **aspen/low forb** - A/LF, **mixed/shrub** - M/S, and **mixed/forb** - M/F. Assumed conditions were 4 mi/h windspeed and no slope. Moisture contents were 1- and 10-hour timelag, 4 and 6 percent; herbs, 150 percent; and live woody plants, 55 to 85 percent.

they are largely untested in aspen forests. The appraisals should be regarded as approximate and applied with full awareness of variability expected in predicting fire behavior in forest and rangeland situations. Accuracy of fire behavior predictions in aspen fuels is discussed further in the appendix.

OTHER FLAMMABILITY FACTORS

Factors in addition to those in tables 5 and 6 can alter fireline intensity and rate of spread: grazing, downed woody fuel accumulations, autumn leaf fall, small patches of conifers, canopy closure, and pocket gopher activity. Except for grazing, the influence of these factors on fireline intensity and rate of spread must be interpreted with judgment. The influence of these factors on flammability is discussed to assist in interpreting tables 5 and 6.

Grazing.—Grazing can greatly reduce flammability where herbaceous vegetation is a significant fuel. Our sampling showed a two-thirds reduction of herbaceous vegetation due to grazing in **aspen/shrub** and **aspen/tall forb** types. Fire behavior predictions of this grazing impact resulted in fireline intensities that were 0.1 of the ungrazed situation. The grazing impact on fire intensity should be less in other aspen fuel types because grasses and forbs are a smaller component of the fine fuels. Nonetheless, the impact is substantial.

Fireline intensities and rates of spread can be adjusted for heavy grazing by multiplying the values in tables 5 and 6 by the following numbers:

Aspen/shrub	0.1
Aspen/tall forb	0.1
Aspen/low forb	0.2
Mixed/shrub	0.2
Mixed/low forb	0.2

Heavy grazing, with few exceptions, negates the opportunity to use prescribed fire in aspen forests. Light grazing prior to burning may be possible, depending upon other factors influencing flammability. For example, mostly cured vegetation and high windspeed may overcome disruption of the fuel bed caused by grazing. Flammability in adjacent areas may be too high, however, to risk an escaped fire from a prescribed burn under these conditions.

Downed Woody Fuel.—Quantities of large downed woody fuels (pieces greater than 3 inches diameter) vary substantially between stands. Fivefold to tenfold differences in loading can be expected between stands. The influence of large woody fuel on fire behavior and fire effects can be substantial, but meaningful quantification of these influences has not been developed.

In mixed stands, accumulations of large woody fuels usually occur with ample quantities of small woody fuels (pieces less than 3 inches diameter). These accumulations contribute to torching of conifers, longer burnout times, and ignition of adjacent fuels. Chances of successful prescribed fire are enhanced by accumulations of large woody fuels. In aspen stands without overstory conifers, however, large woody fuels tend to be less important to fire behavior and successful burning because small woody fuel quantities are inadequate to ignite the large woody fuels (Brown and DeByle 1982).

Substantial quantities of small woody fuels increase fire intensity and hence chances for successful burning. Nevertheless, significant departures from the fireline intensities in table 5 would require extremely high or low quantities of small woody fuels. Such extremes in loading usually occur in patches within burn units, but are not representative of whole burn units.

Autumn Leaf Fall.—Leaf fall does not add greatly to flammability, but in marginal situations it can help sustain fire. The biggest benefit to prescribed burning may be by allowing increased windspeed within aspen stands. Leaf fall, however, often comes when fuel moistures are too high for burning due to rainfall and poor drying conditions.

Small Conifers.—If they can be ignited, patches of conifers in the understory of aspen stands can contribute to successful prescribed burning. Appraising this possibility requires judgment. Rating of fire potential and probabilities of success in the next sections reflect the contribution of conifers to flammability.

Canopy Closure.—Stands having open canopies are more flammable than closed canopies because understory grasses and forbs cure 2 to 4 weeks sooner. Windspeeds at the surface are greater due to reduced wind resistance.

Rodent Activity.—Large populations of pocket gophers reduce the chance of successful prescribed fire by creating mounds of mineral soil that break surface fuel continuity. High windspeeds may be necessary to overcome the fuel discontinuities caused by pocket gopher activity.

Determining Fire Prescriptions

The first step in determining fire prescriptions is to choose good burning opportunities. The previous section on appraising flammability shows that fire behavior

varies considerably in aspen forests. Thus, careful attention to selecting sites capable of sustaining fire spread under prescribed conditions can greatly increase chances of successful prescribed fire.

Table 3 indicates the likelihood of successful prescribed fires according to fuel types. Recent research (Brown 1985) indicates that fires having flame lengths of at least 1.7 to 2.1 ft are required to kill aspen trees. Flame duration should be a minimum of 1 minute. Observations of several prescribed fires also indicate that fires of this intensity should spread unless fuel continuity is broken. Flame lengths and related fireline intensities that can be expected to kill aspen trees and sustain spread are shown in figure 5. Fireline intensities in table 5 should be interpreted with figure 5 to judge the likelihood of prescribed fires being successful.

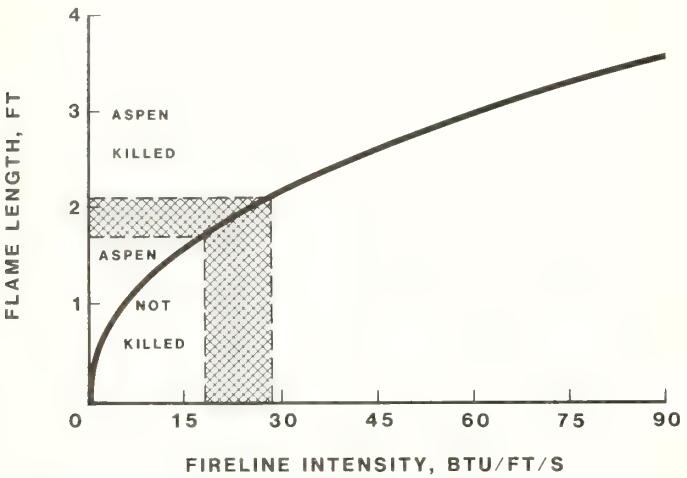


Figure 5.—Flame length versus Byram's (1959) fireline intensity. Flame lengths less than the band at 1.7 to 2.1 ft indicate insufficient fire to kill aspen trees. Fires having flame lengths greater than 1.7 to 2.1 ft are expected to kill aspen trees.

Other factors to consider in planning prescribed fire opportunities include regulation of postfire grazing and size of burn unit. Postburn vegetation is often attractive to big game animals and livestock; thus, the opportunity for animal damage is great. Damage and mortality to aspen sprouts and other vegetation is directly related to intensity of grazing. Tew (1981) reported that a stand of aspen sprouts can be destroyed by 3 successive years of browsing. Sheep are more destructive than cattle. Sprout height regulates the amount of damage by livestock. After sprouts reach 45 inches in height, damage by sheep ceases to be a problem. This requires 3 years of growth on most aspen sites. For cattle, 4 or 5 years are required for suckers to grow out of reach (Sampson 1919). Light browsing of new aspen sprouts can be tolerated because lateral shoots can develop in place of occasional decapitated terminal shoots. In the Intermountain Region the Forest Service recommends that grazing be deferred the first year after burning or until perennials dominate the site and suckers can withstand browsing (USDA 1982). When burning in highly decadent aspen, exclude all ungulate use if possible until new stands have regained vigor. This may require restricted grazing for a number of years.

Large burns of several hundred acres or larger are more cost effective than smaller burns and are less vulnerable to big game damage. Big game, particularly elk, concentrated on wintering grounds can cause extensive damage to aspen sprouts and outweigh the benefits of fire disturbance in aspen (Gruell and Loope 1974; DeByle 1985).

Burning small units close together the same year is one approach to dispersing animal impacts. A single large burn is another approach. In large burn units, flammability typically varies so that a mosaic of burned and unburned vegetation is possible. This may be desirable for wildlife and esthetic reasons. To appraise fire behavior in large burn units, consider the different vegetation and fuel types separately. Whenever possible, large areas should be incorporated in burn units to be most effective in rejuvenating aspen forests. Once good opportunities are identified, prescriptions can be written.

PRESCRIPTION ELEMENTS

Prescription development is the process of first determining the curing, fuel moisture, and wind conditions necessary for a fire to meet the burn objectives. In aspen this primarily involves specifying the marginal burning conditions for a successful fire. Secondly, determine the wind and fuel moisture conditions acceptable for controlling the fire. Also, consider other possible constraints in addition to control.

Wind at midflame height strongly influences fireline intensity as reflected in table 5 and emphasized in figure 6. Judging windspeeds at midflame height is often necessary but results are often imprecise. Many terrain and vegetation features influence wind near the ground. Variability in the windspeed adds uncertainty to writing fire prescriptions and carrying them out. In spite of these difficulties, the technical aids presented here together with experience will lead to effective fire prescriptions.

The following steps illustrate use of fire behavior appraisals to construct a fire prescription:

1. Determine site characteristics such as fuel type and slope. Assume the area to be burned is on a 40 percent slope and in the **aspen/shrub** fuel type.

2. Determine minimal fuel moisture and windspeeds to achieve a successful prescribed fire.

   a. Determine a minimum fireline intensity to achieve a successful prescribed fire. As shown in figure 5, aspen may be killed at fireline intensities of 18 to 28 Btu/ft/s and should be killed at intensities greater than 28 Btu/ft/s. Assume you want to be reasonably certain of an adequately intense fire; thus, choose 28 Btu/ft/s as a minimum fireline intensity. This intensity, corresponding to a flame length of 2.1 ft, also indicates a fire that should maintain sustained spread.

   b. Tabulate from table 5 the curing levels, fine fuel moisture contents, and midflame windspeeds that provide at least the minimum fireline intensity of 28 Btu/ft/s. Assume that 30 percent curing is insufficient to sustain fire spread, so begin the tabulation with 50 percent cur-

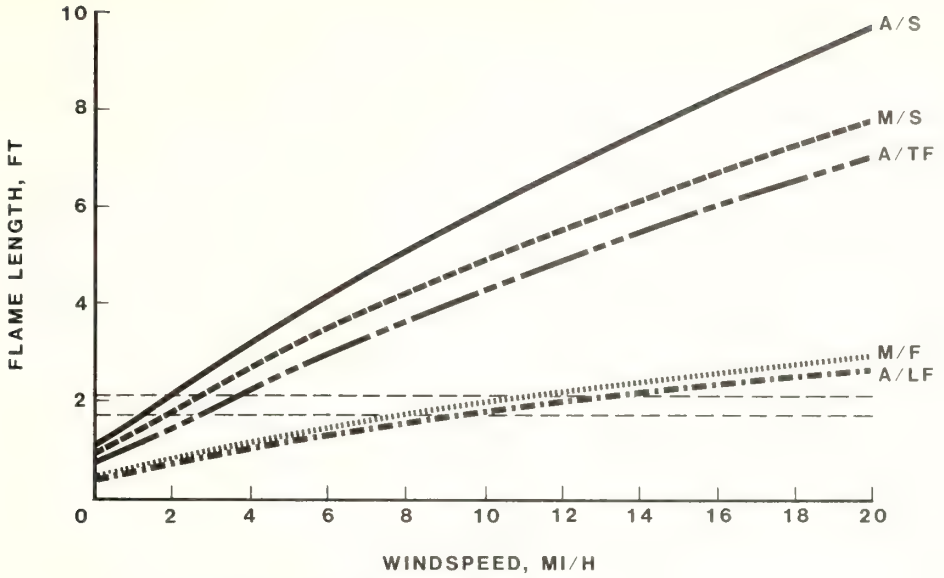


Figure 6.—Flame length influenced by midflame windspeed by fuel types. The dashed lines indicate minimum flame lengths needed to kill aspen trees. Fuel types are abbreviated as in figure 4. Moisture contents were assumed to be 8 and 10 percent for the 1- and 10-hour classes respectively, and curing was assumed to be 70 percent (table 5).

ing (table 8). If desired, the 90 percent curing level could also be tabulated, but preferably the fire prescribed should be possible before this amount of curing. When herbaceous vegetation reaches a highly cured stage, dead fuel moisture contents often remain too high for burning.

c. For each tabulated midflame windspeed, determine windspeeds at 20 ft adjusted for the effects of slope (table 9). Assume fully sheltered fuels in open stands. These are minimum windspeeds for meeting fire objectives.

3. Determine upper limits of flammability for maintaining control of fire. Consider flammability of adjoining areas by evaluating potential for spotting outside of unit and appraising fireline intensity and rate-of-spread potentials in adjoining areas. Rothermel (1983) provides detailed procedures to assist in this task. Also consider values at risk outside the unit and where control of escaped fire is likely. For this example, assume the acceptable limits for fine fuel moisture and windspeed to be 6 percent or less and 20 mi/h or greater than 6 percent and 25 mi/h. The last column in table 8 shows the maximum acceptable windspeed.

4. Summarize the prescription parameters gathered in steps 1 and 2:

Curing	Fine fuel moisture (1-h)	Acceptable 20-ft windspeed
Percent	*Percent*	*Mi/h*
50	4	0-20
50	8-12	6-25
50	16	12-25
70	4	0-20
70	8	0-25
70	12-16	6-25

This summary of fine fuel moistures and adjusted windspeeds is taken directly from the tables provided. Interpolation is necessary when using fine fuel moistures other than those given.

The conditions in step 4 are the most important and also most variable components of a fire prescription. Other components such as relative humidity, air temperature, and National Fire-Danger Rating System indices may be added. They relate to fuel moisture and windspeeds, but can also be useful in themselves to indicate proper burning conditions.

METHOD OF IGNITION

Method of ignition should be carefully considered in planning prescribed fire in aspen because it affects the conditions chosen for burning and chances of success. Both hand-held and aerial ignition methods can be used successfully; however, aerial ignition can be especially effective in burning aspen. Aerial ignition with jelled gasoline permits burning at higher fine fuel moisture contents than possible using hand ignition because more heat can be generated for preheating adjacent fuels, particularly where fuels are abundant and continuous.

Aerial ignition can create larger flames to kill unwanted vegetation and get the fire to spread in marginal fuels. Precise, rapid ignitions are significant advantages of this technique. For example, fuels in aspen forests are frequently sparse and contain high proportions of live vegetation. Aerial ignitions can ignite large areas in a short time, thus helping to draw fire through shrubs and herbaceous vegetation that require substantial preheating for ignition. A better coordinated and more effective ignition pattern is possible, using aerial ignition compared to hand ignition by different

Table 9.—Windspeed at 20 ft adjusted for fuel exposure, slope percent, and midflame windspeed. Dashes indicate small but undefined windspeeds

Slope	Midflame windspeed (mi/h)										
	0	1	2	3	4	5	6	7	8	9	10
Pct	*Mi/h*										
Exposed											
20	-	0-2	3-5	5-8	8-11	10-14	13-15	15-19	17-22	20-24	22-27
40	-	-	-	3-5	5-9	8-12	10-15	13-18	16-20	18-23	21-26
60	-	-	-	-	1-4	4-8	8-11	10-15	13-18	16-21	19-23
80	-	-	-	-	-	-	3-5	6-10	10-13	12-17	15-20
100	-	-	-	-	-	-	-	-	3-6	7-11	10-15
Partially Exposed Fuel											
20	-	0-3	4-7	7-11	11-14	14-18	17-22	20-25	24-28	27-32	30-36
40	-	-	-	4-7	7-12	11-16	15-19	18-23	22-26	25-30	29-33
60	-	-	-	-	2-5	6-10	10-15	15-19	18-23	22-27	26-30
80	-	-	-	-	-	-	4-8	9-12	13-17	17-22	21-26
100	-	-	-	-	-	-	-	-	4-9	10-14	15-19
Fully Sheltered, Open Stands											
20	-	1-4	5-10	11-16	16-22	22-26	27-31	32-36			
40	-	-	-	6-11	12-17	18-22	23-28	29-33	34-38		
60	-	-	-	-	3-8	9-15	16-21	22-27	28-33	34-39	
80	-	-	-	-	-	-	6-11	12-18	19-26	26-32	33-38
100	-	-	-	-	-	-	-	-	7-13	14-21	22-28
Fully Sheltered, Dense Stands											
20	-	2-8	9-22	23-32	33-40						
40	-	-	-	12-22	23-34	35-43					
60	-	-	-	-	6-17	18-30	31-41				
80	-	-	-	-	-	-	13-23	24-35			
100	-	-	-	-	-	-	-	-	16-25	26-39	

individuals, especially where visibility and mobility are hampered at ground level.

The use of fire behavior predictions to determine fire prescriptions applies most appropriately to head fires. Although certain firing patterns, especially when aided by aerial ignition, can develop more intensity than predicted for head fires, fire behavior predictions can help determine prescriptions. Judgment may be required to adjust fire prescriptions based on mathematical predictions for firing patterns expected to generate more intensity than head fires.

Determining When in Prescription

Determining when fuels are ready to burn is more complicated in aspen forests than in most other vegetation types. Curing is probably the most important variable to monitor. Finding the proper time for ignition requires waiting until live fuels are adequately cured and selecting the time when windspeed and dead fuel moistures are in prescription. Adequate curing is particularly important where herbaceous vegetation is the primary fine fuel, such as in the **aspen/shrub** and **aspen/tall forb** types (fig. 4). Curing increases flammability considerably in these types. The tradeoff, however, between waiting for further curing to increase flammability and autumn rains that end the burning season means that aspen stands should be burned as soon as possible. Delays in burning will result in fewer accomplishments because the time in prescription is usually short.

Where herbaceous vegetation is a minor component of the fine fuels, little curing may be necessary. It may be advantageous to burn in the **mixed/forb** type during late summer when dead fuel moisture contents are at their lowest even though live vegetation shows little curing. Conifers may be more readily ignited then to help carry the fire.

CURING TRENDS

Our current study (Brown and DeByle 1982) illustrates curing trends and moisture content of live fuels in aspen stands.

1. Grasses (primarily *Bromus* and *Elymus* spp.) had substantially lower moisture contents and cured at faster rates during early summer than forbs (fig. 7).
2. Forb moisture contents remained very high (200 to 400 percent) during the summer, then dropped substantially over about a 3-week period. Individual forb species apparently vary in the date that an abrupt decline in moisture content begins, as illustrated by comparing *Geranium* with other species (fig. 7). *Rudbeckia, Wyethia,* and *Balsamorhiza* had similar trends.
3. Rainfall during July and August increased moisture contents of grasses and forbs. By September, however, the downward drying trend was set and rain showers did not prolong the curing (fig. 7).
4. Moisture content of shrub foliage and stems varied little throughout August and September. Moisture content of shrub leaves usually remains high until an abscission layer is formed and color change is pronounced.
5. Temperatures in aspen stands at midslope positions are moderate compared to temperatures experienced in openings and valley bottoms. Grasses and forbs cure

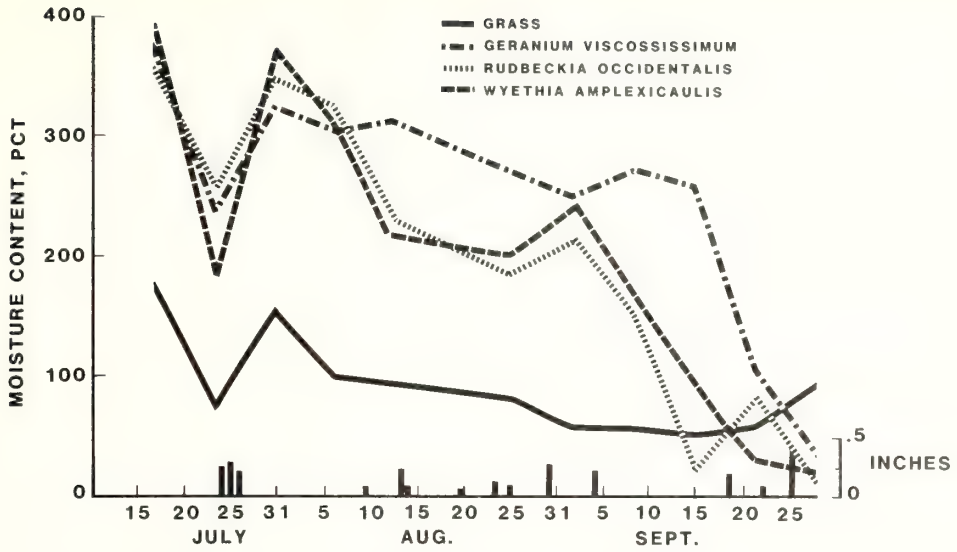


Figure 7.—Moisture content of grasses (*Elymus* and *Bromus* spp.) and forbs from an aspen stand on the Kemmerer Ranger District, Bridger-Teton National Forest, WY, 1981. The bars along the horizontal axis show precipitation.

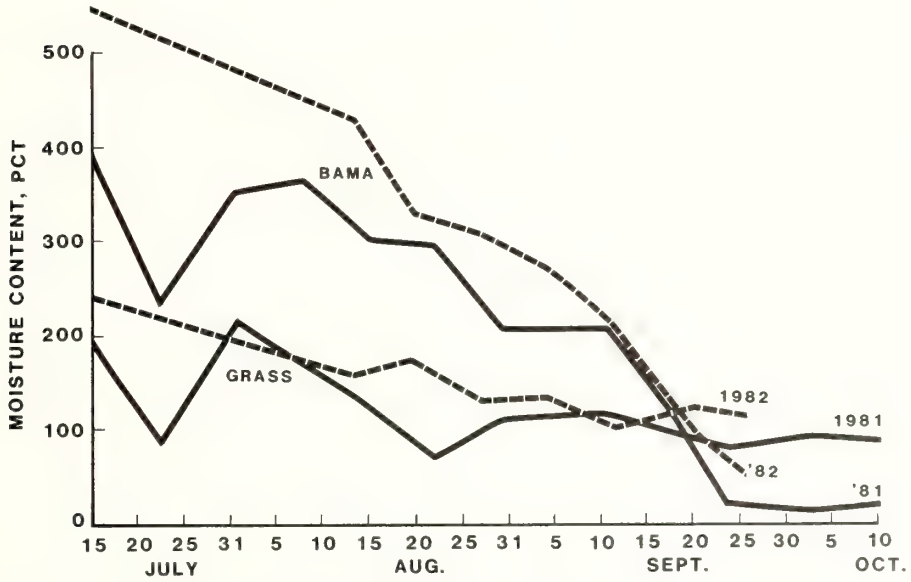


Figure 8.—Moisture content of *Balsamorhiza macrophylla* and grass (*Elymus* and *Bromus* spp.) from an aspen stand on the Kemmerer Ranger District, Bridger-Teton National Forest, WY. Precipitation during August and September was 1.56 inches in 1981 and 4.66 inches in 1982.

more rapidly in openings and under sparse tree canopies. Flammable conditions can be reached 2 to 3 weeks sooner than under full canopies.

6. Under aspen canopies frost damage occurs later than in open areas or than in low-lying areas where cold air collects. Under aspen canopies frost-assisted curing is also delayed. A hard freeze, however, can cure live vegetation quickly. Temperatures less than 15 to 20 °F can cure forbs and shrub foliage in just a few days. If the freeze occurs before abscission layers form, the shrub leaves will remain attached to the stems. This adds to the flammability of surface fuels.

7. In autumn, after most of the herbaceous vegetation is cured and rainfall occurs, some grasses begin growth and greenup near the ground. If the lower 2 inches or more of grass greens up, sustained fire spread becomes very difficult.

8. Drying patterns of herbaceous plants appear to be similar during different years even though precipitation differs through the summer and early fall (fig. 8). Moisture contents in figure 8 were based on small plot samples of all current year's growth, including both live and dead vegetation.

Correlations of live fuel moisture contents with the National Fire-Danger Rating System model of live fuel moistures (Burgan 1979) and with the Keetch-Byram Drought Index (Keetch and Byram 1968) were poor and unsuitable as aids for planning prescribed fires (Brown and others 1983). The best off-site indicator of live fuel moisture contents appears to be simply time of year. Curing progresses steadily through the summer. By early September moisture contents of some plants may have lowered enough to permit fire spread. At this time, on-site evaluation of curing is needed to judge readiness to burn.

ESTIMATION OF CURING

On-site evaluation requires an estimate of the proportion of herbaceous vegetation that is cured. Moisture content of cured vegetation responds like dead fuel to rainfall and atmospheric conditions. Moisture contents of green and transition stage vegetation remain much higher than the cured stage. The difference in moisture contents between green and transition stages in this study was relatively small, especially for forbs (fig. 9). Thus, moisture contents of the green and transition stages can be considered the same for purposes of estimating curing and judging flammability. The transition stage typically is characterized by yellowing of plant parts. Cured leaf tissue shows brown coloration rather than yellow. Cured grass stalks remain straw-colored, but the yellow is largely washed out.

To determine cured vegetation, estimate the proportion of vegetation based on aboveground biomass that is (1) cured, and (2) green, and transition at five or more points in the area to be burned. Locate the points objectively (systematically or randomly) where herbaceous fuels are believed to be important to the success of the fire. Average the estimates and adjust them to total 100 percent. This procedure is simple, but must be carefully done. We have observed a tendency to overestimate the stage of curing that dominates an area by about 10 percent. For example, if most of an area is green, say 70 percent, the visual estimate will be about 80 percent. Look carefully at all herbaceous plant parts from the ground upward. Leaves and small stems should be carefully observed because this material is the fine fuel essential to sustaining fire spread.

Judging the percentage cured is easiest where forbs dominate because differences between stages are distinct. For example, the difference in color and texture of *Wyethia* between transition and cured is evident in comparing figures 10 and 11. The many yellowish leaves in figure 10 are in transition, whereas the brown, curled leaves in figure 11 are cured.

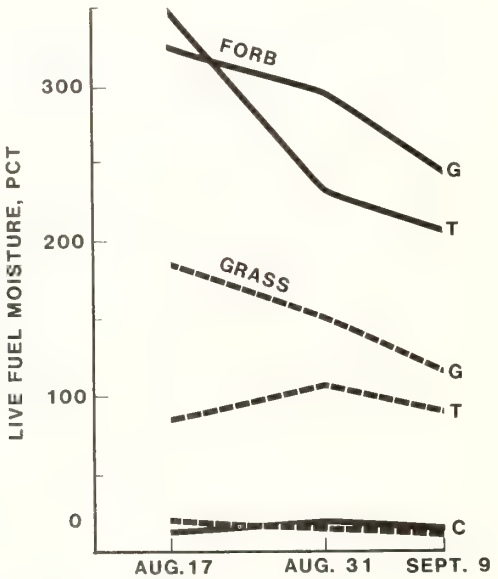


Figure 9.—Moisture contents of green (G), transition (T), and cured (C) components of forbs (*Wyethia amplexicaulis* and *Rudbeckia occidentalis*) and grasses (*Bromus* and *Elymus* spp.) from an aspen stand on the three dates in 1982.



Figure 10.—The dominant forb is mulesears (*Wyethia amplexicaulis*) sheltered beneath an aspen canopy. The proportions of biomass and moisture content were:

	Green	Transition	Cured
		Percent	
Biomass	60	30	10
Moisture	270	235	16



Figure 11.—The dominant forb is mulesears in this open setting. The proportions of biomass and moisture content were:

	Green	Transition	Cured
		Percent	
Biomass	25	20	55
Moisture	200	100	10

Mixtures of grasses and forbs are more difficult to judge because they cure at different rates. Notice, in figure 12, the three stages of curing for the tall forb *Rudbeckia occidentalis*. The cured stage is indicated by the tan- to brown-colored leaves and transition by yellowish leaves. The grass appears green and yellow-green in color and is nearly all in the green and transition stages.

Curing of grasses, particularly perennials, can be deceptive because the seed stalks usually cure before the leaves. Viewed from a distance, this gives a false impression of being mostly cured (fig. 13). A closer look, however, shows that most of the leaves are green. The basal portion of grasses as well as the stalks must be viewed to determine curing level.

After most vegetation has cured, fire spread may still be questionable because grasses green up near the ground following early fall rain (fig. 14).

In addition to estimating curing, it is helpful to evaluate dead fuel moisture contents by either collecting samples of 1- and 10-hour timelag fuels for ovendrying or by measuring moisture content of standard half-inch fuel sticks exposed in or nearby the burn site.



Figure 12.—The mixture of grass and the forb *Rudbeckia occidentalis* occurs in an open stand of aspen and subalpine fir. The grass was 10 percent cured. The proportions of biomass and moisture content for *Rudbeckia* were:

	Green	Transition	Cured
		Percent	
Biomass	20	30	50
Moisture	300	180	12



Figure 13.—Although the grass appears mostly cured, only 30 percent of it is cured. The basal leaves are green. The proportions of biomass and moisture content of the grass were:

	Green	Transition	Cured
		Percent	
Biomass	35	35	30
Moisture	100	75	15



Figure 14.—The forbs, primarily *Rudbeckia*, are 100 percent cured. The perennial grasses, primarily *Elymus* spp. and *Bromus* spp., however, have greened up within 2 inches of the ground, making fire spread improbable.

FUEL MODEL DEVELOPMENT

This section describes additional information about the sampling methods, analysis, and fuel characteristics used to develop the fuel models. First, we grouped aspen forest community types expected to have similar fuels and fire behavior. Community types from each group were then selected for sampling, based on the criteria of having widespread occurrence and being desirable to manage with prescribed fire. Stands were located that represented the chosen community types; then areas of about 0.1 acre were selected within stands for sampling. The vegetation and surface fuels in each selected area appeared to be representative of the stand and community type.

Sampling Procedures

The selected areas were photographed. Three transects were established in a radial pattern from the camera to fully occupy the field of view similar to the method by Fischer (1981). Five sample points were located along each transect. The first sample point was 20 ft from the camera and the others at 15-ft intervals. The following information was obtained at each sample point based primarily upon procedures described by Brown and others (1982):

1. Fuel loading of
   a. herbaceous vegetation (live and dead)
   b. shrubs (live and dead)
   c. downed woody material by diameter classes
   d. forest floor litter or the 01 horizon which includes freshly fallen leaves, needles, bark flakes, other miscellaneous plant parts, and dead matted grass.
2. Duff depth.
3. Cover (percent) of herbaceous vegetation, shrubs, and mineral soil.
4. Density of aspen and conifers.

Fuel depth for use in fire behavior modeling was measured at four equidistant points along the centerline of a 1- by 2-ft subplot. Six subplots were located systematically along the photo plot transects.

Depth was viewed as the average height of vegetation in quarter sections of each subplot. All vegetation less than ¼-inch in diameter in the surface fuel strata was viewed to determine height, except that isolated or spurious pieces of vegetation were disregarded. A gap of 1 ft or more between fuel particles constituted a discontinuity and terminated the upward extent of the surface strata. All vegetation within a vertical extension of the subplot boundary was clipped, dried, and weighed to permit calculation of fuel bed bulk density. Bulk density of litter was determined similarly in five stands.

Fuel Results

Differences and similarities among the fuel types can be evaluated by comparing averages and examining the overlap in ranges (table 10). The community types sampled by fuel type were:

Aspen/shrub
- *Populus tremuloides/Artemisia tridentata*
- *Populus tremuloides/Pachistima myrsinites*
- *Populus tremuloides/Spiraea betulifolia*
- *Populus tremuloides/Prunus virginiana*
- *Populus tremuloides/Shepherdia canadensis*
- *Populus tremuloides/Amelanchier alnifolia*

Aspen/tall forb
- *Populus tremuloides/Rudbeckia occidentalis*
- *Populus tremuloides/Wyethia amplexicaulis*
- *Populus tremuloides/Ligusticum filicinum*
- *Populus tremuloides/Calamagrostis rubescens*
- *Populus tremuloides/Poa pratensis*

Aspen/low forb
- *Populus tremuloides/Berberis repens*
- *Populus tremuloides/Arnica cordifolia*
- *Populus tremuloides/Symphoricarpos oreophilus*

Mixed/shrub
- *Populus tremuloides-Pseudotsuga menziesii/Spiraea betulifolia*

Mixed/forb
- *Populus tremuloides-Abies lasiocarpa/Arnica cordifolia*
- *Populus tremuloides-Abies lasiocarpa/Ligusticum filicinum*
- *Populus tremuloides-Pinus contorta/Calamagrostis rubescens*
- *Populus tremuloides-Pseudotsuga menziesii/Calamagrostis rubescens*

The grouping of community types was tested using data from a different study on fire effects in aspen (Brown and DeByle 1982). Loadings of 0- to ¼-inch downed woody fuel, herbaceous vegetation, shrubs, and total fine fuels, and percentage of shrub cover from 15 stands were compared with the range in loadings for the fuel types in table 9. Only shrub loadings for two of the 15 stands fell outside the fuel type ranges. The fuel classification appeared to be reasonable based on this test.

In our data shrub cover and shrub loadings were imprecisely related, primarily because of the large range in shrub sizes sampled. Thus, shrub loadings can vary widely with coverage. The practical implication is that the 30 percent coverage, which separates the shrub understory classes from the forb understory classes, is only an approximate guide to appraising flammability.

Table 10.—Average and range in values of the sampled fuel quantities, shrub and mineral soil coverages, and duff depths by the standard aspen fuel types and modified fuel types

Fuel type	N	Downed woody material (inches) 0-¼	¼-1	1-3	3+	Litter	Herb	Foliage	Shrub Stems 0-0.25 in Total	Small conifer	Coverage Shrub	Mineral soil	Duff depth
						--- Pounds/acre --					--- Percent ---		Inches
						Standard							
Aspen/shrub													
mean	9	500	1,980	4,760	16,680	1,710	720	750	1,140	3,440	30	41	6	1.1
high		720	3,580	8,660	34,460	2,810	1,000	1,740	1,810	6,140	210	58	19	2.3
low		210	450	2,140	5,520	420	390	430	620	980	0	31	2	0
Aspen/tall forb														
mean	5	210	1,050	5,730	23,460	1,760	1,140	120	110	250	20	15	6	1.5
high		540	1,590	14,770	60,300	2,600	2,020	550	400	980	90	58	15	2.6
low		40	520	610	0	790	230	0	0	0	0	0	2	4
Aspen/low forb														
mean	5	530	2,070	3,120	4,460	1,350	300	90	60	260	180	11	12	6
high		750	3,170	4,090	8,880	2,740	460	220	110	630	440	25	23	1.2
low		370	880	1,830	1,350	170	180	0	0	0	0	0	2	4
Mixed/shrub														
mean	2	940	3,300	2,730	2,340	1,980	90	830	1,100	3,040	20	63	2	8
high		1,250	3,830	3,310	3,400	2,040	90	1,040	1,340	3,670	30	70	2	1.3
low		630	2,770	2,150	1,280	1,920	80	610	860	2,480	0	56	2	.3
Mixed/forb														
mean	5	480	2,230	5,100	17,080	1,680	290	160	190	630	940	15	6	1.4
high		1,180	3,700	8,350	31,040	2,560	550	370	570	1,400	4,150	29	14	2
low		260	1,180	2,650	8,620	740	10	20	70	100	0	6	3	1
						Heavy Downed Wood								
Mixed/forb														
mean	2	1,250	4,290	6,310	61,850	2,720	170	20	20	40	900	4	5	2.1
high		2,070	5,410	6,990	71,260	3,660	290	40	30	80	1,550	4	2	2.8
low		420	3,170	5,640	52,440	1,770	50	0	10	10	240	4	2	1.3
						Grazed								
Aspen/shrub														
mean	1	210	770	970	6,500	1,060	330	250	420	1,000	10	14	38	0
Aspen/tall forb														
mean	4	220	1,480	3,450	22,450	1,320	480	20	40	80	70	3	8	4
high		410	3,090	6,010	70,180	2,880	790	70	110	210	264	9	14	1
low		120	280	2,520	3,140	380	340	0	0	0	0	0	3	1

Fuel bulk densities ranged from 0.47 to 1.26 lb/ft^3 for litter and from 0.006 to 0.095 lb/ft^3 for grasses, forbs, and shrubs (upright vegetation). The average bulk densities, surface fuel depths, and number of stands sampled were as follows:

Fuel	Number stands	Depth	Bulk density
		Feet	*Lb/ft^3*
Litter	5	0.043	0.95
Upright			
Aspen/shrub	8	1.3	.068
Aspen/tall forb	2	1.1	.026
Aspen/low forb	4	.5	.023
Mixed/shrub	2	1.1	.066
Mixed/forb	3	.6	.022

Shrub understories were about 3 times more dense than forb understories. The litter fuel was 15 to 45 times more densely packed than the upright fuel. The aspen litter and upright fuels were 2 to 5 times less dense than observed in conifer surface fuels (Brown 1981).

Loading of litter, which is primarily comprised of aspen leaves where aspen dominates the overstory, is not easily predicted. Litter loadings varied greatly among stands (table 10). Examination of scattergrams revealed lack of relationships between stand basal area and loading of litter as well as loading of herbaceous vegetation. The absence of relationship between aspen basal area and understory production was also observed by Severson and Kranz (1976). Woods and others (1982), however, found a relationship between understory production and basal area for stands having similar site characteristics. Productivity increased substantially for canopy coverage of less than about 50 percent.

Aspen leaves are a potentially flammable fine fuel. More than 1,000 lb/acre of leaves and twigs may be added to the forest floor at the time of leaf fall (Bartos and DeByle 1981). But the leaves often are not on the ground at the right time for burning or arranged to favor combustion. Leaves shed in the autumn decompose and deteriorate considerably over winter, spring, and summer prior to the next burning season. Leaves may fall too late to be available for burning during the current year. In stands without a high coverage of ungrazed herbaceous vegetation, the leaves fall flat on the ground, which is unfavorable for combustion. The importance of leaf litter to attaining successful prescribed fire must be evaluated on a site-specific basis.

Fire Prediction

The fuel models for the five aspen and mixed fuel types were established by using average loadings of fuel components to generate fire behavior predictions using program FIREMOD (Albini 1976) for each fuel type.

This fire behavior was compared with fire behavior averaged from predictions made for individual sample stands. Based on this comparison, some loadings of individual fuel components were then altered to yield fire behavior that we believe better reflected the relative differences between fuel types. Lastly, four fuel components were formed by condensing the 11 fuel components; then, the BEHAVE system was used to generate the fire predictions shown in this guide. The original and final fuel components were:

Original components	Final components
Dead fuel	
Herbaceous vegetation	
Shrub foliage	
Shrub stemwood, 0- to ¼-inch diameter	1-hour timelag
Downed woody fuel, 0- to ¼-inch diameter	
Litter	
Shrub stemwood, ¼- to 1-inch diameter	10-hour timelag
Downed woody fuel, ¼- to 1-inch diameter	
Live fuel	
Herbaceous vegetation	Herbaceous
Shrub foliage	
Shrub stems, 0- to ¼-inch diameter	Woody plants
Shrub stems, ¼- to 0.8-inch diameter	

Net loadings and surface area-to-volume ratios of the final fuel components were weighted by a surface area factor based on the proportion of surface area in a set of defined fuel component subclasses (Albini 1976). As a result, the loadings of the final components in the fuel models are less than the loadings actually sampled in the field.

Fuel properties held constant in predicting all fire behavior were:

Property	Value
Low heat value, Btu/lb	8,000
Particle density, lb/ft^3	32
Total mineral content, fraction dry	0.055
Effective mineral content, fraction dry	0.01
Dead fuel moisture of extinction, fraction dry	0.25

Particle surface area-to-volume ratios were:

Component	Ratio
	Ft^2/ft^3
Shrub foliage	3,000
Herbaceous vegetation	2,800
Shrub stems, 0- to ¼-inch diameter	600
Shrub stems, ¼- to 1-inch diameter	175
Downed woody fuel, 0- to ¼-inch diameter	400
Downed woody fuel, ¼- to 1-inch diameter	90
Litter	1,500

BEHAVE Fuel Models.—Fuel loadings, particle surface area-to-volume ratios, and fuel depths used in BEHAVE to generate tables 5 and 6 are shown in table 11. Fuel depth was determined by weighting litter and upright surface fuel depths by their respective loadings:

$$D = \frac{L_w \times L_d + S_w \times S_d}{L_w + S_w}$$

where

D = fuel depth, ft

L_w = loading of litter, lb/ft^2

L_d = depth of litter, ft

S_w = loading of live and dead herbaceous vegetation and shrubs, lb/ft^2

S_d = depth of herbs and shrubs, ft.

Moisture contents of live herbaceous vegetation remained constant for all curing levels, but varied with curing levels for live shrubs (table 12). Quantities of cured herbaceous vegetation and shrub foliage were treated as dead fuel in predicting fire behavior. Thus, as curing increased, loadings of dead herbaceous vegetation and shrub foliage increased, while the live loading decreased. Transferring live fuel to the dead fuel category produced an effect on fire behavior analogous to a large change in live fuel moisture content.

Additional fire behavior predictions can be generated using the aspen fuel model parameters (table 11) in the BEHAVE system. If you want to change the fuel inputs in table 11 because you have fuel data from the field, we suggest that you compare your fuel loading values with the range of values in table 10. If your fuel loadings fall within the range of our data, we advise against making changes because fuel loadings determined in the field often need interpretation before they can be used appropriately in a fuel model.

The 1-hour fuel loading inputs to BEHAVE are not direct field weights. They contain several 1-hour fuel size class components that were combined through a surface area weighing procedure using program FIREMOD (Albini 1976). If you do choose to alter fuel loading inputs, we suggest changing the values in table 11 in proportion to the difference between your field values and the average loadings in table 10.

The fuel appraisal and fire prediction information presented here is intended to assist managers in planning and conducting prescribed fires. It is largely new information to applying prescribed fire in aspen and should be used with judgment in making plans and decisions.

Table 11.—Aspen fuel model parameters used in BEHAVE[1]

Curing level	Loading				Surface area/volume				Depth
			Live				Live		
	1-hour	10-hour	Herb	Woody	1-hour	10-hour	Herb	Woody	
Pct	*Tons/acre*				*Ft^2/ft^3*				*Ft*
				Aspen/shrub					
0	0.800	0.975	0.335	0.403	1,400	109	2,800	2,440	0.65
30	.893	.975	.234	.403	1,620	109	2,800	2,440	.65
50	1.056	.975	.167	.333	1,910	109	2,800	2,310	.65
70	1.218	.975	.100	.283	2,090	109	2,800	2,090	.65
90	1.379	.975	.033	.277	2,220	109	2,800	1,670	.65
				Aspen/tall forb					
0	.738	.475	.665	0	1,480	109	2,800	-	.30
30	.930	.475	.465	0	1,890	109	2,800	-	.30
50	1.056	.475	.332	0	2,050	109	2,800	-	.30
70	1.183	.475	.199	0	2,160	109	2,800	-	.30
90	1.309	.475	.067	0	2,240	109	2,800	-	.30
				Aspen/low forb					
0	.601	1.035	.150	0	1,400	109	2,800	-	.18
30	.645	1.035	.105	0	1,540	109	2,800	-	.18
50	.671	1.035	.075	0	1,620	109	2,800	-	.18
70	.699	1.035	.045	0	1,690	109	2,800	-	.18
90	.730	1.035	.015	0	1,750	109	2,800	-	.18
				Mixed/shrub					
0	.880	1.340	.100	.455	1,350	109	2,800	2,530	.50
30	.906	1.340	.070	.455	1,420	109	2,800	2,530	.50
50	1.037	1.340	.050	.364	1,710	109	2,800	2,410	.50
70	1.167	1.340	.030	.290	1,910	109	2,800	2,210	.50
90	1.300	1.340	.010	.261	2,060	109	2,800	1,800	.50
				Mixed/forb					
0	.754	1.115	.150	0	1,420	109	2,800	-	.18
30	.797	1.115	.105	0	1,540	109	2,800	-	.18
50	.825	1.115	.075	0	1,610	109	2,800	-	.18
70	1.167	1.115	.045	0	1,670	109	2,800	-	.18
90	.884	1.115	.015	0	1,720	109	2,800	-	.18

[1]Heat content of 8,000 Btu/lb and moisture of extinction of 25 percent were used for all models.

Table 12.—Live fuel moisture contents and percentage of dead shrub foliage related to herbaceous curing levels

Curing level	Shrub foliage dead	Live fuel moisture	
		Herb	Shrub
	Percent		
10	0	150	85
30	0	150	85
50	25	150	75
70	50	150	65
90	75	150	55

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APPENDIX: ACCURACY OF FIRE BEHAVIOR PREDICTIONS

The fire spread model (Rothermel 1972) used as a basis to predict fireline intensity and rate of spread is largely untested in aspen fuels. Only results of the limited tests described here have been reported. We conducted four test fires on the Bridger-Teton National Forest in a *Populus tremuloides/Rudbeckia occidentalis* community type (Youngblood and Mueggler 1981) where the primary fine fuel was grass (*Elymus* and *Bromus* spp.). Three of four fires did not sustain fire spread (table 13) because the herbaceous fuels were too green. In the fire that did sustain spread, there was good agreement between predicted and observed flame lengths.

The mathematical fire model (Rothermel 1972) has demonstrated reasonable accuracy in a variety of fuels, including conifer slash, grass, southern rough (Andrews 1980), and black spruce in Alaska (Norum 1982). In 131 experimental fires (Andrews 1980), nearly half of the observations were within 25 percent of over- or under-prediction. Observed and predicted flame lengths in the black spruce agreed closely.

When applied to aspen fuels, the model's accuracy remains uncertain. Experience and observations gained on fires in aspen should be used to help interpret the fire model results in this publication. Improved application of fire behavior predictions can result.

Table 13.—Observed and predicted flame lengths according to fuel conditions and windspeed on test fires in aspen stands having an understory dominated by herbaceous plants

Fire	Date	Loadings				Cured	Moisture content			Midflame wind-speed	Flame length	
		Shrub	Herb	Downed woody[1]	Litter	herb[2]	1-h	Litter	Herb[3]		Obs.	Pred.
		Lb/acre				*Percent*				*Mi/h*	*Ft*	
1	8/18	0	130	730	1,690	15	7	7	150	1.5	0	0.3
2	8/18	0	670	200	1,040	25	7	8	130	8	0	1.0
3	8/19	0	670	200	1,040	25	7	8	130	2.0	0	1.4
4	9/23	0	700	220	360	50	5	7	75	3.5	1.5	1.3

[1]Twigs and branches 0 to 1 inch in diameter.
[2]Percent of herbaceous biomass that is dead.
[3]As average moisture content of all live and dead grasses and forbs occurring at sample locations.

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Brown, James K.; Simmerman, Dennis G. Appraising fuels and flammability in western aspen: a prescribed fire guide. General Technical Report INT-205. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 48 p.

Describes a method for appraising fuels and fire behavior potential in aspen forests to guide the use of prescribed fire and the preparation of fire prescriptions. Includes an illustrated classification of aspen fuels; appraisals of fireline intensity, rate of spread, adjective ratings for fire behavior and probability of burn success; and evaluations of seasonal change in live fuel moisture contents.

KEYWORDS: fuel moisture, fire behavior, fuel model, fire effects, community type

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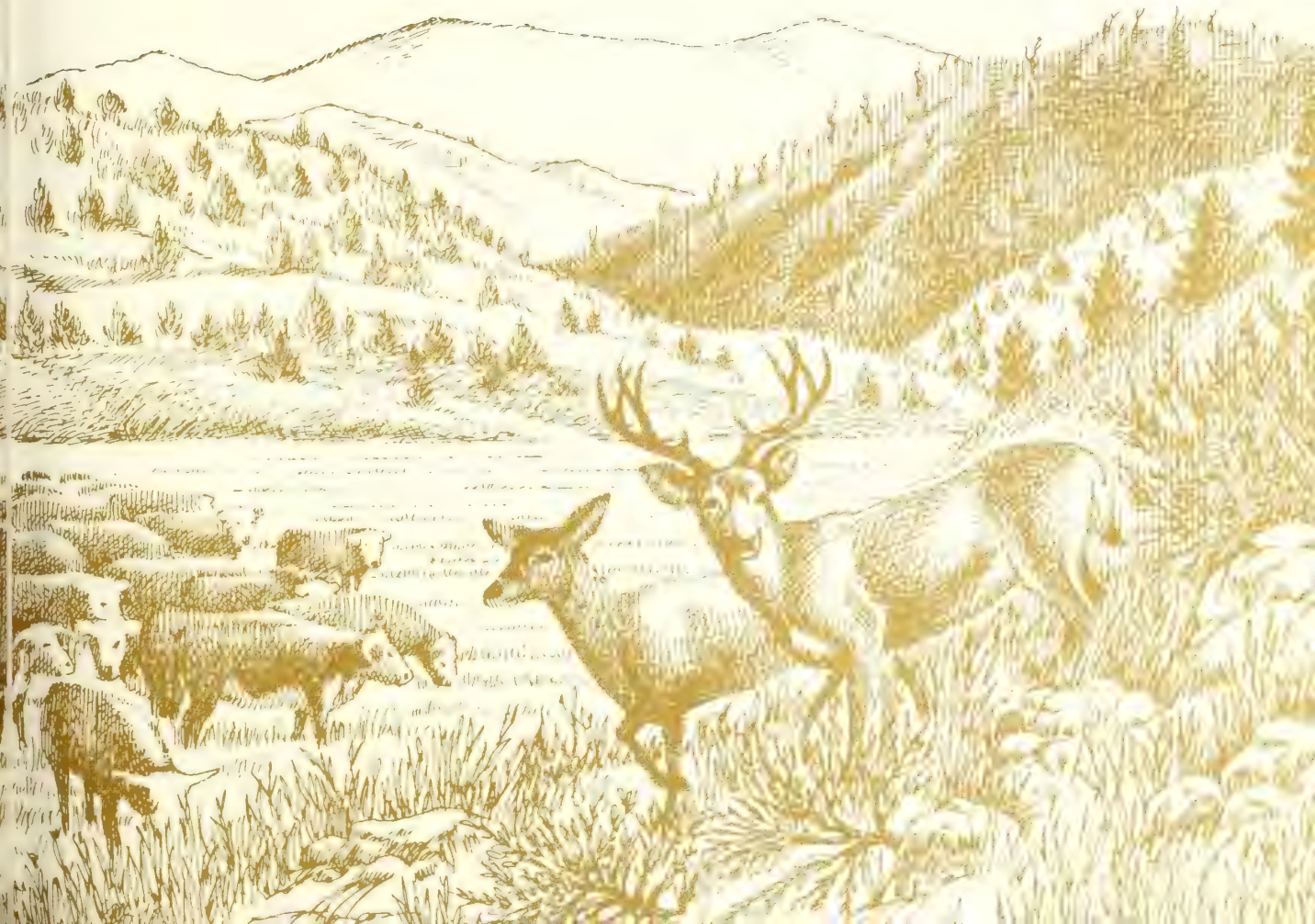
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Post-1900 Mule Deer Irruptions In The Intermountain West:

Principle Cause and Influences

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RESEARCH SUMMARY

This report evaluates four hypotheses for the dramatic increase in mule deer populations that occurred in the Intermountain West between the early 1930's and mid-1960's:

1. Succession of rangelands from grass dominance to dominance by woody plants created vast expanses of optimum mule deer habitat.
2. Conversion of coniferous forests to shrubfields by logging and wildfire improved mule deer habitat, especially the availability of browse.
3. Conservation and predator control dramatically reduced deer mortality.
4. Reductions in numbers of livestock on the open range increased the amount of forage available to mule deer.

The author's investigations of mule deer populations, mule deer ecology, and long-term trends in plant communites support hypothesis 1—succession of grasses to woody plants was the principal cause of the mule deer irruptions; the remaining hypothetical factors contributed but were not critical. The invasion of woody plants was set in motion by intensive grazing, which suppressed or eliminated competing grasses, and by a marked reduction in the size, intensity, and frequency of fires, which had periodically eliminated and suppressed woody plants, and had maintained ranges that were predominantly bunchgrasses. The absence of fire was brought about by the reduction in potential fuels by intensive grazing, elimination of Indian ignitions, breakup of fuel continuity by development of ranches, communities, and roads, and organized fire suppression.

Conversion of forests to shrubfields by logging and wildfire affected a relatively small part of the West, hence had localized impact on deer numbers. Similarly, conservation and predator control, and reductions in livestock numbers, alone could not have been more than contributing factors.

Mule deer habitats reached the optimum balance of trees, shrubs, and herbs during and following a period of extreme disturbance by livestock grazing and absence of fire on the open range, and fire and logging in the forests. In recent decades this habitat has deteriorated as succession proceeds toward overly large, dense stands of shrubs and trees that are not as productive as in former years. The productivity of mule deer habitats in the Intermountain West can only be restored and maintained by reintroducing or simulating the perturbations that created them: judicious use of grazing, logging, and prescribed fire.

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Post-1900 Mule Deer Irruptions in the Intermountain West:
Principal Cause and Influences

George E. Gruell

INTRODUCTION

Between the early 1930's and the mid-1960's, mule deer (*Odocoileus hemionus*) populations irrupted in the Intermountain West: the States of Montana, Wyoming, Idaho, Utah, and Nevada. Speculation about the causes of the irruption can be hypothesized as follows:

1. Succession of rangelands from dominance by grasses to dominance by woody plants that constitute superior mule deer habitat (Julander 1962; Leopold 1950; Longhurst and others 1976).
2. Conversion of forests to shrubfields by wildfire and logging, which generally resulted in improved deer habitat, particularly availability of browse (Lyon 1969; Pengelly 1963).
3. Conservation and predator control dramatically reduced deer mortality (Leopold and others 1947; Rasmussen and Gaufin 1949).
4. Reduction in numbers of livestock on the open range increased the amount of forage available to mule deer (Rasmussen and Gaufin 1949; Salwasser 1976).

The author's observations of mule deer populations and his studies of plant communites in the Intermountain West support hypothesis 1—that succession from grass dominance to trees and shrubs that comprise optimum mule deer habitat was indeed the principal reason for the explosive increase in mule deer numbers after 1930, to which the other factors contributed.

Although various authors have speculated on the causes of succession toward woody plants—commonly attributed to disruption of grasses by intensive grazing or absence of fire—none has treated these factors in great depth. The principal contribution of this report is to provide additional insight into how this vast transformation in plant communities came about, particularly the role of fire prior to and after settlement of the Intermountain West. A discussion of the fire ecology of western rangelands, with emphasis on the implications for mule deer habitat, constitutes most of the dissertation on hypothesis 1.

An ancillary goal of this report is to forge an environmental perspective that will provide a more effective basis for managing mule deer populations, which heretofore has been mainly regulating the size of the harvests. Mule deer habitats reached optinum condition earlier in the century in response to various perturbations—intensive grazing and fire suppression on the open ranges, wildfire and logging in the forests. In recent years, this habitat has declined in quality, mainly because of the absence of fire, and it will continue to decline unless periodically rejuvenated by judicious grazing, logging, and prescribed burning.

Marked reductions in mule deer populations following the mid-1960's (Julander and Low 1976) are not addressed in this paper. In retrospect it appears that this phenomenon was the result of several interrelated factors including a deterioration in habitat quality, marked decline in fawn production, and sustained high hunter harvest that reduced the breeding population and increased effectiveness of predation on a reduced deer population.

HYPOTHESIS 1: SUCCESSION FROM GRASS DOMINANCE TO DOMINANCE BY WOODY PLANTS

Most of the support for hypothesis 1 is devoted to an analysis and description of the plant communities of the Intermountain West prior to settlement, their succession from grasses to woody plants, and the agents that set succession in motion. Because fire had such a profound influence on this phenomenon, this section includes an extensive dissertation on the fire history and fire ecology of Intermountain rangelands and forests. To enable the reader to evaluate important relationships between the transformation of the plant communities and the deer irruption, particularly timing, geographic scope, relative numbers of animals, and the implications of succession on deer habitat, the section on plant communities is preceded by brief reviews of the deer irruption and mule deer ecology. Much of the evidence presented in support of hypothesis 1 is also germane to discussions of hypotheses 2, 3, and 4.

Mule Deer Populations

It is commonly believed that mule deer were relatively few in the Intermountain West prior to and during the early stages of Euroamerican settlement (Julander and Low 1976; Leopold and others 1947; Leopold 1950). These conclusions, however, were largely based on records from Utah and California. A review of written accounts covering Montana, Wyoming, Idaho, Utah, and Nevada (appendix 1) suggests that there were regional differences in early mule deer population levels.

Mule deer were apparently common or even plentiful in some localities in Montana, Wyoming, and perhaps central Idaho, whereas in other localities they were

uncommon or scarce. An exaggerated idea of mule deer numbers may have been formed, however, in instances where the observer did not distinguish between mule deer and whitetailed deer (*Odocoileus virginianus*). "Deer" reported in bottomland habitats were probably whitetailed deer, not mule deer. An exaggeration of mule deer numbers may also derive from reports of winter concentrations comprised of animals from low-density summer ranges.

The early record suggests scarcity of mule deer in Utah, Nevada, and southern Idaho. Only two accounts were found that described the presence of deer, and these were localized winter concentrations. Reports from northern Nevada during Hudson Bay Company expeditions from 1826 to 1831 are particularly noteworthy because they make no mention of deer despite numerous hunting excursions in mountain ranges that later supported great numbers of mule deer.

Leopold (1950) suggests that, before Euroamerican settlement, mule deer were found principally where forest and grasslands met, or on recent burns. Pengelly (1963) reports that most early accounts in northern Idaho referred to the abundance of deer (including mule deer) on the forest edge. Both authors emphasized seral vegetation in forests as being essential to production of deer.

During the mining and homesteading era (1847 to 1900), mule deer were subjected to extreme exploitation. By 1900, numbers had been seriously depleted in Utah (Rasmussen and Gaufin 1949). Julander and Low (1976) report similar conditions in other western States. In 1917, for example, the deer population in Nevada's 600-mi^2 Ruby Mountains was reported to number about 50 animals (1917 Annual Wildlife Reports, Humboldt National Forest files [USDA Forest Service 1917]). Borell and Ellis (1934) concluded from a 1927 survey in the Ruby Mountains that the low deer population reflected marginal habitat, and that this mountain range would never support large numbers of deer.

My conversations with longtime Nevada residents during the mid-1950's revealed that sighting a deer was a novelty until the 1930's, and tracks were a subject worthy of discussion. Julander and Low (1976) tell of an oldtimer in Utah who recalled as a youth (around 1900) following the tracks of a deer 4 consecutive days before getting a fleeting glimpse of the animal. Similar accounts have been given by early residents of Montana (Bayless 1975). For example, Koch (1941) reported that the sighting of a single deer, elk, or sheep during the 1890's was most unusual.

Mule deer populations began increasing regionally in the 1930's. In Wyoming, Murie (1951) reported that mule deer in the Jackson Hole region were scarce prior to 1930, but increased remarkably by 1950. By the mid-1950's the Nevada Fish and Game Department estimated that the Ruby Mountains population numbered between 25,000 and 30,000 animals. In Utah the mule deer population was estimated to have increased from 8,500 in 1916 to a peak of 375,000 in the 1945-50 period. Idaho officials estimated that their deer population (including whitetailed deer) increased from 45,000 in 1923-24 to 315,000 in 1963 (Julander and Low 1975).

Mule Deer Habitat Preferences

Most authorities agree that mule deer are primarily browsers and, therefore, benefit from increases in shrubs. Various research supports this assumption (Kufeld and others 1973; McAdoo and Klebenow 1979). Shrubs are particularly important during winter months (Hill 1956). Key plants in a north-central Utah study were big sagebrush (*Artemisia* spp.) and mountain-mahogany (*Cercocarpus* spp.) (Richens 1967). In the Bridger Mountains of Montana, Wilkins (1957) concluded that big sagebrush, bitterbrush (*Purshia tridentata*), and Rocky Mountain juniper (*Juniperus scopulorum*) constituted the major items in the diet of wintering deer. In the Missouri River Breaks, big sagebrush was the single most important browse plant (Mackie 1970). Big sagebrush was also the most important food consumed over the critical winter months in the Lassen-Washoe and Inyo Ranges in California and Nevada (Leach 1956). When viewed in the context of yearlong diets, forbs often comprise a large portion of forage intake on summer ranges (Kufeld and others 1973; Lovaas 1958; Wilkins 1957). Green grass usually comprises most of the diet during a short period of initial spring growth.

Various studies have demonstrated that snow depth and duration on winter range are a major determinant of mule deer population levels (Edwards 1956; Picton and Knight 1969; Robinette and others 1952; Wallmo and Gill 1971). Most mule deer winter ranges are snow covered at least part of the winter. Thus, it appears that conversion of ranges from herb dominance to shrub dominance improved forage availability and nutritional quality, particularly during stress periods when all but the taller forage species were snow covered. Winter survival of deer proved to be better on these shrub-dominated ranges (Harper 1968).

The importance of cover, including favorable terrain, has also been widely recognized. During severe weather deer abandon good food supplies in favor of protection (Loveless 1967). The clearing of pinyon-juniper woodland in New Mexico improved food quality, but the absence of cover apparently reduced habitat quality enough to limit use by deer (Short and others 1977). Expansion of pinyon-juniper into grasslands and shrublands increased the capacity of these ranges to support wintering mule deer up to the point where trees began displacing forage plants. Expansion of Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), and ponderosa pine (*Pinus ponderosa*) has produced comparable results on mule deer winter ranges in Montana (Gruell 1983).

Long-Term Vegetative Trends

Although game managers have generally accepted the theory of conversion of western ranges from dominance by grasses to shrub dominance, there has been marked disagreement among plant ecologists and range scientists over the extent of the change. Early researchers concluded that much of the Intermountain West currently occupied by sagebrush communities was grassland at the time of settlement (Clements and Clements 1939; Shantz and Zon 1924). Regional studies of plant succession have supported this view

(Christensen and Johnson 1964; Cooper 1960; Cottam and Stewart 1940; Hull and Hull 1974; Stoddart 1941). Conclusions were based on historical descriptions of vegetation and studies of sites that had not been disturbed for long periods.

Others citing historical records, studies of relatively undisturbed sites, and soils analyses have concluded that the sagebrush/grass vegetation type is ecologically stable and its boundaries closely resemble those that existed at the time of settlement by Euroamericans (Tisdale and Hironaka 1981). Blaisdell (1953) reported that before settlement the major part of the upper Snake River Plains was probably an open stand of sagebrush and other shrubs, beneath which was a vigorous stand of perennial grasses and forbs. Vale's (1975) analyses of 29 emigrant journals covering major travel routes through Wyoming, Idaho, Nevada, Oregon, and Colorado, led him to conclude that shrubs (principally sagebrush) visually dominated pristine vegetation. Those holding to the viewpoint of historical dominance by sagebrush believe that sagebrush did not invade grassland on a large scale. Instead, they contend that heavy livestock grazing eliminated or reduced palatable grasses and forbs, and allowed an increase in the size, density, and vigor of sagebrush (Hironaka and others 1969).

EVIDENCE FROM HISTORICAL ACCOUNTS

Because of the disagreements on the presettlement occurrence of sagebrush and bunchgrass in the Intermountain West, I undertook the following analysis of historical accounts of vegetation (appendixes 2 and 3) (see fig. 1 for approximate locations). This analysis differs from others because it distinguishes the vegetation of the plains and semiarid valleys from that of the more productive mountain valleys and slopes. Past interpretations have either focused on a few localized areas or considered vegetation over vast areas encompassing wide variation in site potential.

The early records in appendix 2 indicate that before Euroamerican settlement, sagebrush covered extensive areas of the plains and semiarid valleys. Depending upon geographical location and elevation, average annual precipitation varied between 8 and 15 inches. Sagebrush was particularly abundant on sandy, gravelly, or clayey soils, and on basalt (Bradley 1873; Endlich 1879; McKinstry 1975; Raynolds 1868). Early travelers considered these regions barren or sterile because of the dominance of sagebrush and other semidesert shrubs. Sagebrush was also widely distributed in the driest valleys (8 to 10 inches precipitation) where soils were more productive. Here, surface soil moisture deficiencies apparently limited growth of bunchgrass and favored the deep-rooted sagebrush.

Sagebrush did not dominate plains and semiarid valleys where retention of soil moisture was high, such as the upper Snake River Plains transition zone near the present site of St. Anthony, ID (Bradley 1873). Bunchgrass was conspicuous in these areas, particularly in riparian zones (Endlich 1879; Haines 1971; Raynolds 1868; Simpson 1876).

In contrast to the plains and semiarid valleys, early accounts suggest that vegetation on mountain valleys and slopes (appendix 3) was visually dominated by bunchgrass. Such sites have good potential for supporting grass because their fine-textured soils have good moisture retention capacity and they receive 10 to 25 inches of precipitation. Much of this land has been converted into irrigated pastures and dryland farms.

Over broad areas that have not been cultivated, comparison of early descriptions of vegetation with current vegetation suggests a conversion from dominance by bunchgrass to woody vegetation. For example, in Montana's Ruby Range, the rolling hills beautifully clothed with bunchgrass described by Russell in 1835 are no longer covered with grass, nor are the hills in the Monida Pass locality dominated by yellow bunchgrass as described by Stuart in 1857. In Wyoming, the middle fork of Owl Creek is still covered by grass (Jones 1875), but the Cottonwood and Gooseberry Creek drainages that were once grass covered are now dominated by sagebrush. In Idaho, sagebrush and juniper are the dominant vegetation on the hills between Bear River and Malad, while sagebrush predominates in the Henry's Lake area. These regions were described as being grass covered in the 1840's and 1870's (Fremont 1887; Hayden 1872). Utah's Mountain Meadows described in 1844 by Fremont and in 1851 by Pratt evidently changed from grass dominance to shrub dominance by 1877 (Cottam and Stewart 1940). In Utah's Cache Valley, dense stands of sagebrush became established in grasslands by the late 1880's (Hull and Hull 1974). The grass cover on the slopes in eastern and central Nevada described in 1859 by Kern is no longer conspicuous, nor is bunchgrass the major vegetal component in the Secret Pass and Emigrant Pass localities of northeastern Nevada. Today, shrubs and cheatgrass comprise the primary vegetation in these regions. Visual dominance of bunchgrass on mountain valleys and slopes was interrupted by sagebrush dominance wherever soil productivity was low. In 1843, while in southwestern Idaho, Fremont (1887) observed:

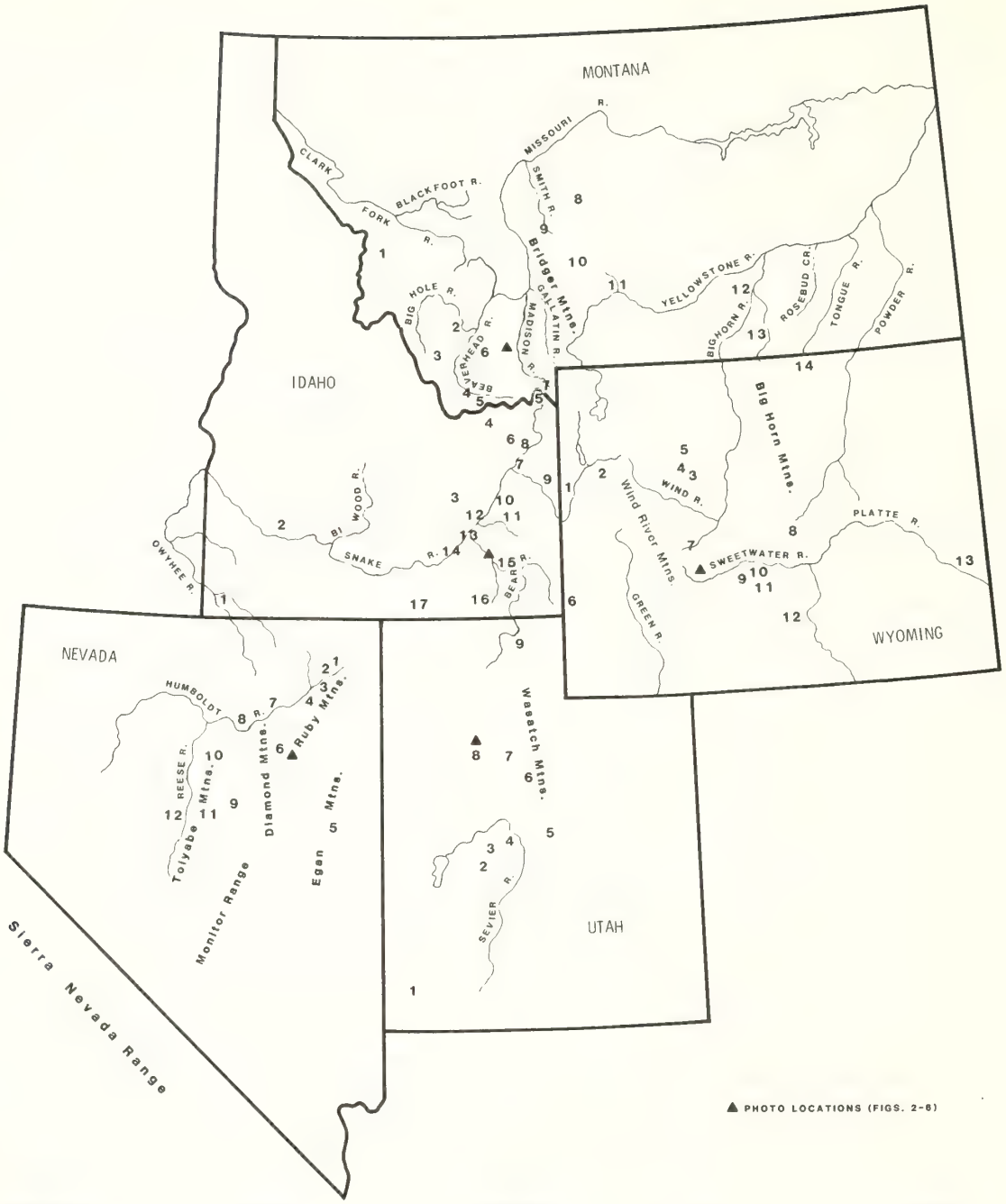
> This plant [sagebrush] loves a dry, sandy soil and cannot grow in the good bottoms where it is rich and moist; but on every little eminence, where water does not rest long, it maintains absolute possession.

By inference, Fremont's statement suggests that grasses commonly occupied deep soils. Because sagebrush was capable of growing on these sites, there is reason to believe that it was excluded by fire.

EVIDENCE FROM HISTORICAL PHOTOGRAPHS

Further perspective on the condition of early vegetation in the Intermountain West can be had by comparing historical photographs with matched retakes. This is the only means of visually evaluating long-term vegetal changes over wide geographical areas. Care should be exercised in accepting the original photograph as a reliable measure of the presettlement condition because there is evidence that significant vegetal changes had occurred in some localities by the late 1800's.

Changes in vegetation have been documented by means of photo-retakes in Montana (Phillips 1963;



MONTANA

1- BITTERROOT VALLEY
2- MELROSE VALLEY
3- HORSE PRAIRIE
4- RED ROCK CR.
5- MONIDA PASS
6- RUBY RANGE
7- RAYNOLD'S PASS
8- LITTLE BELT MTNS.
9- SMITH VALLEY
10- SIXTEEN MILE CR.
11- BIG TIMBER CR.
12- HARDIN
13- LITTLE HORN CR.

IDAHO

1- OWYHEE PLATEAU
2- MOUNTAIN HOME
3- ATOMIC CITY
4- PLEASANT VALLEY
5- HENRYS L.
6- SNAKE RIVER PLAINS
7- REXBURG
8- ST. ANTHONY
9- TETON BASIN
10- RIRIE
11- TAYLOR MTN.
12- BLACKFOOT
13- POCATELLO
14- AMERICAN FALLS
15- LAVA HOT SPRINGS
16- MALAD
17- RAFT R.

WYOMING

1- JACKSON HOLE
2- GROS VENTRE R.
3- OWL CR.
4- COTTONWOOD CR.
5- GOOSEBERRY CR.
6- COKEVILLE
7- POPO AGIE R.
8- RATTLESNAKE HILLS
9- SWEETWATER PLATEAU
10- JEFFERY CITY
11- CROOK'S GAP
12- RAWLINS
13- LARAMIE PLAINS
14- SHERIDAN

UTAH

1- MOUNTAIN MEADOWS
2- PAVENT VALLEY
3- HOLDEN
4- ROUND VALLEY
5- EPHRAIM CANYON
6- SPANISH FK.
7- UTAH L.
8- TOOLE VALLEY
9- CACHE VALLEY

NEVADA

1- THOUSAND SPRINGS
2- BISHOP CR.
3- WELLS
4- SECRET PASS
5- STEPTOE VALLEY
6- HUNTINGTON VALLEY
7- ELKO
8- EMIGRANT PASS
9- ROBERTS CR.
10- SIMPSON PARK RGE.
11- BIG SMOKY VALLEY
12- REESE RIVER VALLEY

Figure 1.—Locations of sites in appendixes 1 and 2.

USDI, BLM 1979, 1980; Houston 1982; Gruell 1983), Wyoming (Phillips 1963; Progulske 1974; Gruell 1980; Houston 1982), Idaho (Gruell 1983), Utah (Rogers 1982), and Nevada (Gruell 1966). Comparison of the original scenes with modern retakes, spanning 100 years or more, shows expansion of shrub and tree cover at the expense of herbaceous vegetation. The extent of change varies with each site's potential to produce woody plants, disturbances, and amount of elapsed time between photos. Photos retaken in semiarid rangelands after a relatively short interval (about 40 years) showed the least amount of change. In contrast, scenes retaken after 100 years or more on mesic sites showed marked increases in woody vegetation.

Five photo pairs (figs. 2-6) were selected as representative of successional changes in vegetation types within the mountain valley and slope environments comprising mule deer habitats. The criteria for photo selection were visual clarity and length of time elapsed since the date of the original photograph. The early scenes in Montana, Wyoming, and Nevada are from my past studies. Those in Utah and Idaho were supplied by others. Pre-1900 photographs were preferred because they allowed evaluation of vegetation changes over a relatively long time period. Nonetheless, the "original photographs" probably reflect successional advances beyond what would be expected prior to occupancy by Euroamericans when fire was the major disturbance factor.

Vegetative cover types represented by historical photographs include:

Figure 2. Montana - Douglas-fir/bunchgrass
Figure 3. Wyoming - Lodgepole pine/limber pine/ sagebrush/bitterbrush
Figure 4. Idaho - Juniper/bitterbrush
Figure 5. Utah - Juniper/sagebrush
Figure 6. Nevada - Pinyon/juniper/mahogany

Analysis of these early photographs (figs. 2a-6a) shows that:

1. Smooth slopes characteristically were covered by grasses or a mixture of shrubs and grasses.
2. Crown-sprouting or cloning shrubs and trees were in an early seral condition.
3. Conifers were largely restricted to ridges, rock outcrops, or mesic sites.
4. Conifer cover was sparse in the canyon bottoms.

By comparison, the analysis of the modern retakes (figs. 2b-6b) shows that:

1. Smooth slopes and canyon bottoms have often become dominated by conifers.
2. Crown sprouting or cloning shrubs and trees such as willow, aspen, and chokecherry have increased in frequency and size.
3. There has been an increase in fire-sensitive shrubs preferred by mule deer including sagebrush, bitterbrush, and curlleaf cercocarpus (*Cercocarpus ledifolius*)(curlleaf mountain-mahogany).

Although not apparent in the photographs, important browse plants including bitterbrush (fig. 4b), sagebrush (fig. 5b), and mountain-mahogany (fig. 6b) are being displaced by conifers. With advancing succession, browse plants pictured in figs. 4b and 6b are also being lost as a result of defoliators and boring insects.

Historical narratives and photographic evidence suggest that, before settlement by Euroamericans, bunchgrasses were the predominant vegetation in mountain valleys and on slopes that comprise the great majority of mule deer habitats. The relative distribution of bunchgrass and sagebrush seems to have been strongly influenced by available soil moisture. In general, the mountain valleys and slopes have a higher potential for growth of bunchgrasses than plains and semiarid valleys because of more productive soils and greater precipitation. Bunchgrass production on plains and semiarid valleys was apparently limited by insufficient soil moisture resulting from low precipitation, coarse or clayey soils, and persistent drying winds. These environments were characteristically covered by an expanse of sagebrush, except for stands of bunchgrass wherever soils were suitable.

These interpretations are in disagreement with those who have concluded that the early landscape was dominated by sagebrush. Supporters of the sagebrush dominance theory (Vale 1975) have cited journals covering primary travel routes through plains and semiarid valleys where sagebrush is the indicated climatic climax vegetation. This evidence does not properly consider mountain valleys and slopes that comprise a significant part of the landscape.

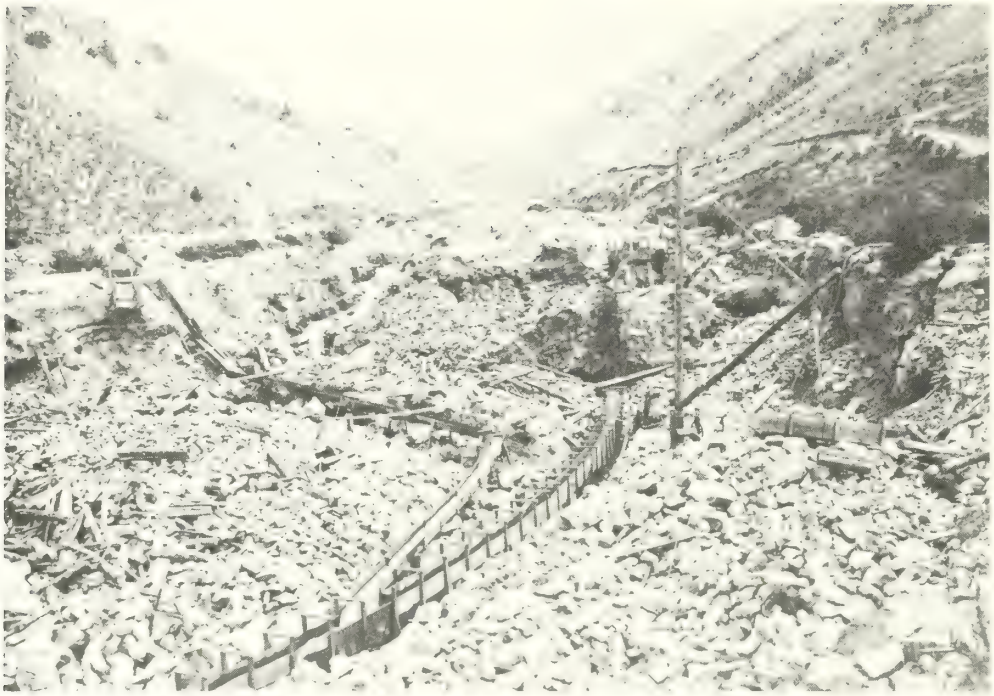


Figure 2a.—1871. An east-northeast view (elevation 6,000 ft) up Alder Gulch above Virginia City, MT. Placer mining following discovery of gold in 1863 caused extreme disturbance of canyon bottom. The south facing bluebunch wheatgrass covered slope at left supports a few mature Rocky Mountain juniper in rock outcrops. Juniper and Douglas-fir regeneration is evident. Conifers on north facing slope at right are Douglas-fir. Stumps in area indicate light cutting of trees. Wildfires had been relatively frequent in this locality. Examination of two fire-scarred stumps showed evidence of four fires before 1871. Photograph by W. H. Jackson, courtesy of Montana Historical Society.



Figure 2b.—July 28, 1981. (110 years later.) The large Douglas-fir in left foreground (arrow) is the same one pictured in original scene. Regeneration of Douglas-fir and Rocky Mountain juniper on this slope has produced a marked change. Canyon bottom now supports various shrubs and trees including aspen, narrow leaf cottonwood, willow, and chokecherry. North slope is densely covered by Douglas-fir. Photograph by G. E. Gruell.



Figure 3a.—August 1870. A northwest view of Chief Washakie's Shoshone encampment on Willow Creek; Wind River Mountains, WY (elevation 8,200 ft). Shrubs in foreground appear to be sagebrush. Snags in distance show evidence of slopes having been swept by fire. W. H. Jackson photograph, courtesy of Colorado Historical Society.



Figure 3b.—July 27, 1967. (97 years later.) Scene shows more landscape at left than original. Improved soil moisture from irrigation favored growth of herbs and willow in bottomlands. Slopes in distance support lodgepole pine and limber pine. A mixture of sagebrush and bitterbrush covers bench on right. Photograph by G. E. Gruell.



Figure 4a.—July 1907. Looking west across Mink Creek at a point about 6 miles from its confluence with the Portneuf River in southeastern Idaho (elevation 5,400 ft). Juniper on distant slopes are restricted to south exposures where they were protected from frequent presettlement fires. The dark shrubs are bitterbrush that appear to be closely grazed. Note predominance of herbs in foreground. Prof. Toumey photograph, courtesy Douglas Turner.



Figure 4b.—September 8, 1982. (75 years later.) In the absence of fire, juniper has markedly increased by spreading to deeper soils. Bitterbrush has also increased in density and size. Arrow points to expansion of chokecherry and other shrubs. The general increase in woody vegetation is illustrated in foreground. Photograph by G. E. Gruell.



Figure 5a.—1901. Facing north from a point 3 miles east of Skull Valley Indian Reservation near road to Dry Canyon, Stansbury Mountains, UT (elevation 5,900 ft). Benchlands support Utah juniper that are largely confined to areas of shallow soil. Stumps indicate a low level of cutting. Big sagebrush is the predominant shrub. Gilbert photograph, courtesy USGS.



Figure 5b.—September 3, 1976. Juniper has increased in all areas, and young trees and seedlings are abundant. The increase has been greatest in the areas of low slope angle and least on the mountain slopes at right. Photograph by Gary Rogers, photograph courtesy of Gary Rogers and the University of Utah Press.



Figure 6a.—1868. Looking east-southeast down canyon from a point about 1.5 miles above Flyn and Hager Spring in Ruby Valley, NV (elevation 7,500 ft). Open slope in midground appears to be covered by herbs and snowberry. Curlleaf mountain-mahogany, pinyon, and juniper are confined to rocky areas where they have been protected from fire. Note regenerating aspen on lower-left edge of photo (arrow). Timothy O'Sullivan photograph, courtesy USGS.



Figure 6b.—July 31, 1982. (114 years later.) The absence of fire for over 114 years has allowed woody vegetation to proliferate. Aspen at bottom-left have matured (open arrow). Photograph by G. E. Gruell.

	Poor or/ dry sites	Better or/ moist sites
Climatic climax[1]	Sagebrush	Sagebrush
Pre-1900 Fire Climax	Sagebrush	Bunchgrass

[1]Found on modern "undisturbed sites" where fire has been suppressed.

Figure 7.—Postulated bunchgrass and sagebrush occurrence as influenced by site potential and disturbance

The sagebrush dominance theory has also been arrived at by study of relatively "undisturbed" or "relic" areas that are approaching a "climatic climax" condition. This approach does not consider prior history of disturbance. It assumes that these sites represent presettlement conditions, but overlooks evidence of frequent fires and hence the fire climax that prevailed prior to settlement (fig. 7). Post-1900 measurements invariably represent a vegetal state that had been altered by extreme livestock grazing and a prolonged period of fire's absence. Consequently, the amounts of fire-sensitive sagebrush and herbs recorded are not indicative of presettlement vegetative conditions. Tisdale and Hironaka (1981) recognized the potential of fire to create temporary grasslands within the sagebrush/grass regions. As will be discussed in more detail, this may be why grasslands prevailed across the more productive landscapes prior to settlement.

Reasons for Vegetative Changes

Several reasons have been advanced for the change from grass to shrub dominance. In the Southwest, Hastings and Turner (1965) concluded that a shift to woody vegetation was climatically influenced. But, Cooper (1960) saw no evidence of a large-scale climatic change in the past 1,000 years. Likewise, tree ring analysis in eastern Oregon by Keen (1937) revealed no general trend toward wetter or drier years during the past 650 years.

Two of the more probable causes for vegetal change are livestock grazing and fire. Both of these factors will be examined. Understanding their respective roles should help determine where they fit in future management of mule deer habitats.

INFLUENCE OF LIVESTOCK GRAZING

Many investigators studying mule deer have agreed that on western grass ranges the grazing of domestic livestock triggered growth of successional food plants preferred by deer (Leopold 1950; Julander and Low 1976; Longhurst and others 1952, 1981; Salwasser 1976; Urness 1976). Intensive grazing of rangelands occurred from the mid-19th-century settlement up to (in some cases) the present time. The period of heaviest grazing was generally from 1880 to 1930 (Urness 1976). Leopold (1950) concluded that overgrazing in central and western California allowed expansion of chaparral at the expense of grassland and oak woodland. He suggested that similar shrub invasions occurred widely throughout the Great Basin as a result of past grazing. Longhurst and others (1976) reported that east of the Sierra and Siskiyou Mountains, and in the Great Basin range type, early cattle and sheep impacts were primarily responsible for reduction of native perennial grasses and establishment of shrubs. This conclusion was also reached for the 11 western States (Longhurst and others 1981). Severe depletion of Utah's grasslands as a result of excessive domestic livestock grazing gave rise to an abundance of browse-producing shrubs (Frischknecht and Plummer 1955; Julander and Low 1976). For example, important species such as bitterbrush, sagebrush, curlleaf mountain-mahogany, and rabbitbrush (*Chrysothamnus* spp.) increased in abundance (Julander 1962; Urness 1976; Salwasser 1976).

Extreme soil disturbance and depletion of herbaceous plants were believed to be primary factors in establishment of shrubs and trees. Serious reduction or virtual elimination of competing perennial grasses and palatable forbs especially contributed to shrub and tree establishment (Julander 1962).

INFLUENCE OF FIRE

There is worldwide evidence that fire has been a major perturbating factor affecting plant succession over millenniums (Stewart 1951; Pyne 1982). Generally, wildlife biologists and others associated with mule deer management have not fully appreciated the past role of fire. A few investigations, however, have suggested that exclusion of fire favored a shift to shrub dominance, thus allowing mule deer increases (Harper 1968; Julander 1962; Salwasser 1976; Urness 1976). But neither evidence of past fires nor the ecological role of fire has been discussed.

An understanding of fire history and fire ecology is essential to interpreting long-term trends in vegetation. Questions include: How often did early fires burn? How large were they? How did these fires affect vegetation? How did Euroamerican settlement affect fire frequency and size? Has the absence of fire influenced growth of vegetation?

Early Fire Occurrence.—In the scientific and historical literature, I found 145 published accounts of early-day fires in Montana, Wyoming, Idaho, Utah, Nevada, and eastern Oregon (Gruell 1985b). This is by no means an exhaustive listing. The frequency and size of early fires seem to have varied, depending on topography, potential ignition source, weather, and fuels. Denig (Ewers 1961), Catlin (1891), and Havard (1878) report that extensive fires swept the grasslands of central and eastern Montana every year during the period 1832 to 1877. In forested regions of Montana, very large fires occurred during exceptionally dry years such as 1889 when about 530 mi^2 burned on the Lewis and Clark Forest Reserve, including portions of the Lewis and Clark, Flathead, and Lolo National Forests (Ayres 1901). Elsewhere, extensive

fires were reported in 1834 in western Idaho and eastern Oregon by Captain Bonneville (Todd 1961) and by Captain Nathaniel Wyeth (Young 1899); in 1875 and 1878 in southeastern Idaho by Beaver Dick Leigh (Thompson and Thompson 1982); and in western Wyoming in 1879 by Thomas Moran (Fryxell 1943). Grass-covered valleys and uplands in southern Idaho, northern Utah, and south-central Montana burned frequently (Gruell 1985b). In contrast, Bonneville's observations in 1832 suggest that fire was rare in areas like the Laramie Plains in Wyoming, where sparse fuels would not carry fire (Todd 1961). Sparsely vegetated regions in the drier sagebrush valleys also yield few early reports of fire.

The probability of fires occurring at lower and middle elevations was strongly influenced by the level of Indian activity. Of the 145 accounts of fire found in the literature, 41 percent were attributed to ignitions by Indians (Gruell 1985a). The apparent reasons for setting fires included communication, warfare, hunting, forage enhancement, food gathering, and clearing vegetation (see Barrett 1981). Escaped fires were undoubtedly common. Lightning also caused many fires, especially at higher elevations, although the historical literature surprisingly makes little mention of this. Fires were sometimes also carelessly ignited by fur trappers during the presettlement era (Haines 1971; Stevens 1855). During the late 1800's prospectors apparently caused many fires, particularly in the mountains where mining was occurring (Leiberg 1904).

Fire history studies based on analysis of fire-scarred trees have provided quantitative information on past fire periodicities in the Northern and Middle Rocky Mountains of Montana, Wyoming, Utah, and the Owyhee Plateau of Idaho. These studies confirm that fires were frequent in semiarid regions of the Intermountain West. Average pre-1900 fire intervals were 4 to 20 years in ponderosa pine/Douglas-fir forests in the Bitterroot Valley of western Montana (Arno and Peterson 1983). Fire scar dates from higher and cooler Douglas-fir/mountain big sagebrush (*Artemisia tridentata vaseyana*) ecotones in Yellowstone Park and southwestern Montana suggest fire intervals varied from 20 to 40 years (Houston 1973; Arno and Gruell 1983). Shorter intervals evidently prevailed in grassland-aspen associations. For example, fire-scarred aspen in Ephraim Canyon, UT, showed a mean fire interval of from 7 to 10 years during the period 1770 to 1875 (Baker 1925). Burkhardt and Tisdale (1976) report presettlement fire intervals in southwestern Idaho sagebrush-grass/western juniper (*Juniperus occidentalis* ssp. *occidentalis*) ecotones were about 11 years. In general, fires have been less frequent (50 to 300 years or longer) in moist or subalpine regions of the Northern Rockies (Loope and Gruell 1973; Romme 1979; Arno and Davis 1980; Barrett 1982).

Fire Effects on Vegetation.—A few early travelers recognized that fire promoted grasses and suppressed shrub development (Gruell 1985b). In southwestern Montana, Mullan (1855) wrote: "In many places the valley has been burnt over, and the young, green grass is now growing abundantly."

In August 1843, on the lower Bear River in Utah, Fremont (1887) observed the presence of young willows. He noted that older trees were rarely found because Indians burned the plains to produce better grass.

Cooper (1961) and Daubenmire (1968) report that fire enhances grass production and suppresses woody plants. Fire in grasslands generally promotes seed production, germination, and establishment of grass seedings (Vogl 1979).

Fire severity has a strong influence on the recovery rate of grasses. Severity is primarily influenced by fuel loading and season of the fire. Study of grass response following a late-summer prescribed fire in dense sagebrush on the upper Snake River Plains resulted in slow recovery of fine bunchgrasses such as Idaho fescue (*Festuca idahoensis*) and needle-and-thread grass (*Stipa comata*) where the burn was hot (Blaisdell 1953). Coarse grasses including thickspike wheatgrass (*Agropyron dasystachyum*), plains reedgrass (*Calamagrostis montanensis*), and bluebunch wheatgrass (*Agropyron spicatum*) recovered rapidly. Burning of grassy fuels containing little woody material often results in rapid recovery of bunchgrasses because the residence time of the fire is short and temperatures are not extreme.

Big sagebrush is readily killed by fire (Blaisdell 1953). It is an important component in the diet of wintering mule deer (Bayless 1975; Leach 1956; Richens 1967), and it supplies needed cover. The importance of this plant to mule deer underscores the need to understand fire relationships. In the more productive mountain valleys and slopes that comprise most mule deer habitats, vegetation burned frequently, thus inhibiting the development of sagebrush. The historical record suggests that the presence of sagebrush is largely dictated by the elapsed time since the last fire. Fire intervals of 1 to 20 years would relegate sagebrush to widely scattered plants or patches depending on topography. Expansive fire-climax grasslands with little sagebrush would have prevailed on smooth topography where fuel continuity allowed fires to carry over extensive areas. Because of the scattered distribution and low occurrence of its seed source, sagebrush recovery potential would have been much slower than today.

The effect of early fires on bitterbrush, an important winter forage of mule deer, was apparently one of inhibiting stand establishment and development. Bitterbrush is considered fire sensitive (Nord 1965; Wright and others 1979), but it responds differently to fire because of genotypic variations (Wright and others 1979; Bunting and others 1985). Decumbent forms sprout more readily after top removal than do open growth forms. Plant mortality seems to be influenced by one or more factors including fire intensity (Blaisdell 1953), phenology (Mueggler and Blaisdell 1958), soil moisture (Nord 1965), and soil texture (Driscoll 1963). A medium-intensity prescribed fire through antelope bitterbrush in northwestern Montana during the spring resulted in a 33 percent loss of plants (Bumstead 1971). Late-summer prescribed burns on eastern Idaho sagebrush ranges killed two-thirds of the bitterbrush (Pechanec and others 1954). Summer wildfires of moderate intensity in eastern

Oregon have removed entire stands of bitterbrush (Countryman and Cornelius 1957).

Fire frequency appears to have been an important factor affecting presettlement distribution and density of bitterbrush. An extreme effect is suggested in Oregon where experimental annual spring burning beneath ponderosa pine over a 21-year period left only a few scattered, stunted plants in the larger openings (Weaver 1961; 1967). Historical photographs in the Bitterroot Valley of western Montana show evidence that frequent fires (7-year intervals from 1600 to 1900) severely limited development of bitterbrush (Gruell and others 1982). Considering the sensitivity of bitterbrush seedlings to fire, it is highly probable that a fire frequency of 5 to 20 years would result in sparse distribution and low density of bitterbrush.

Curlleaf mountain-mahogany, a weak sprouter, is an important forage plant for wintering mule deer. Investigations suggest that fire effects differed, depending upon whether mountain-mahogany was seral to conifers or represented the potential climax vegetation (Gruell and others 1985). For example, mountain-mahogany associated with moist subalpine fir (*Abies lasiocarpa*) habitat types was subjected to infrequent, stand-destroying fires, after which new stands of mountain-mahogany developed from seedlings. In contrast, mountain-mahogany growing in drier communities was confined to rocky sites or thin soils where sparse fuels limited fire spread. These sites afforded protection for mountain-mahogany. Expansion of mountain-mahogany was restricted because seedlings were unable to become established on deeper soils where fuel accumulations resulted in frequent fires.

Before settlement, grass or sagebrush/grass regions now covered by juniper and pinyon/juniper woodlands were subjected to frequent wildfires (Burkhardt and Tisdale 1976; Leopold 1924). Fires restricted trees to ridgelines or sites where fuels were sparse (fig. 4).

There is much evidence that frequent fires in the pinyon-juniper types can maintain a grassland setting, and conversely that lack of fire will result in development of woodlands (Arnold and others 1964; Barney and Frischknecht 1974; Dwyer and Pieper 1967; Jameson 1962). Recurrent fires retard juniper encroachment (Gartner and Thompson 1972; Wedel 1957), and young juniper trees up to 4 feet high are highly susceptible to fire mortality (Dwyer and Pieper 1967; Jameson 1962).

Presettlement fires apparently had varying effects on crown-sprouting shrubs and trees such as ceanothus (*Ceanothus* spp.), willow (*Salix* spp.), mountain maple (*Acer glabrum*), Gambel oak (*Quercus gambelii*), aspen (*Populus tremuloides*), chokecherry (*Prunus emarginata*), and serviceberry (*Amelanchier* spp.). Postfire response depended upon plant species, fire severity, fire periodicity, and site conditions. Historical photographs and recovery and growth rate studies suggest that shrub species growing in ponderosa pine, in dry Douglas-fir, and in nonforested environments where grass fuels were abundant were suppressed by frequent surface fires (Cooper 1961; Gruell and others 1982; Gruell 1983). In contrast, in moist conifer forests infrequent stand-replacement fires and moderate intensity thinning fires removed conifer competition and allowed development of early successional vegetation.

Reduced Fire and Plant Response.—Fire's influence on vegetation in the Intermountain West was dramatically reduced following Euroamerican settlement. This change resulted from several interrelated factors (Gruell 1983). Of primary importance was relocation of Indians from their ancestral territories to reservations, thus removing a major ignition source. Introduction of domestic livestock and yearly consumption of fine fuels checked the possibility of extensive spreading fires. Development of irrigated pastures and construction of roads broke up fuel continuity, thereby limiting fire spread. By the early 1930's, with development of an effective fire suppression system, fire potential was substantially reduced.

The absence or marked reduction of fire over extensive areas has favored the development of fire-sensitive plants, including sagebrush, bitterbrush, and curlleaf mountain-mahogany. Big sagebrush has increased manyfold on productive sites in Montana (Gruell 1983), Wyoming (Gruell 1980), and Nevada (Gruell 1966). In southwestern Montana, fire scar data suggest that this trend coincided with a fire-free period of about 80 to 130 years (Arno and Gruell 1983). On the Klamath Indian Reservation in Oregon, Weaver (1957) reported that expanded distribution and increased density of bitterbrush resulted from 40 to 50 years of fire exclusion. In western Montana, a great increase in bitterbrush was found in a ponderosa pine forest where wildfire has been excluded since about 1900 (Gruell and others 1982). Hazeltine and others (1961) report that establishment of bitterbrush stands in Elko County, NV, in about 1890 resulted from livestock reductions following the severe winter of 1889-90. There are strong implications, however, that heavy livestock grazing had eliminated the possibility of fire, thus allowing bitterbrush to proliferate.

In fire's absence, curlleaf mountain-mahogany has increased greatly on productive sites that had been subjected to frequent surface fires (Gruell and others 1985). Most mountain-mahogany stands on deeper soils are less than 125 years old and have increased on these sites as a result of removal of fine fuels by livestock and absence of fire (Scheldt 1969; Dealy 1975; Gruell and others 1985).

Burkhardt and Tisdale (1976) reported that invasion of western juniper into a big sagebrush community on the Owyhee Plateau appeared to be directly related to a marked reduction in fires starting in the 1870's. At Mountain Meadows, UT, Cottam and Stewart (1940) recorded a 500 percent increase in Utah juniper (*Juniperus osteosperma*) between 1862 and 1934. They concluded that this dramatic increase was best explained by the elimination of grass competition by livestock. Subsequent studies such as Burkhardt and Tisdale (1976) would suggest, however, that the absence of fire was the primary reason for juniper increases.

The photo pairs in figures 2 through 6 show an increase in the number and size of fire-sensitive shrubs and trees as well as crown sprouting shrubs and trees. The same vegetal trend is documented in other photographic comparison studies cited previously. As suggested by fire history studies, historical accounts of fire,

and aging of shrubs, this trend is largely the result of lack of fire over long periods.

Summary—Hypothesis 1

The case for hypothesis 1 may be summarized as follows: The irruption of mule deer that occurred early in the 20th century was too pronounced, widespread, and persistent to be an ordinary population fluctuation and therefore was probably due to some dramatic ecological change. The quality of mule deer habitat is determined by the abundance of nutritious forage, a high percentage of which is in the form of palatable shrubs, and stands of small trees to provide cover and shelter. Prior to settlement, frequent fires favored grasses and inhibited widespread development of shrubs and trees, except on rocky or moist sites. Settlement brought pronounced disruption of existing plant communities. Intensive grazing suppressed and sometimes destroyed the grasses, allowing an invasion of forbs and woody plants. Consumption of fuels by livestock, elimination of Indian ignitions, development of irrigated croplands, roads, and communities, and the advent of organized fire suppression brought a marked reduction in numbers, size, and intensity of fires. Thus, succession from grasses to forbs and woody plants was allowed to proceed. Eventually, a new assemblage of herbs, shrubs, and trees constituted mule deer habitat far superior to the pristine dominance of grasses; hence mule deer populations irrupted throughout the Intermountain West.

HYPOTHESES 2 THROUGH 4

Hypothesis 2: Conversion of Conifer Forests to Seral Shrubs

Large increases in mule deer populations have been attributed to conversion of conifer forests to successional shrubfields. Logging and fire on summer ranges in the Sierra Nevada Mountains benefited mule deer by opening up conifer stands and allowing midsuccessional shrubfields to proliferate (Longhurst and others 1952; Salwasser 1976). Pengelly (1963) concluded that logging and fire in Northern Rocky Mountain Douglas-fir/ponderosa pine forests temporarily increased deer forage. In this region, a noticeable increase in mule deer numbers and harvest was observed on timberlands during the 1950's. Lyon (1969) likewise reported that unusually large fires in the Northern Rocky Mountains in 1910 and 1919 created thousands of acres of seral, high-quality brushfield habitat. Deer and elk populations increased in the favorable environment and reached unprecedented highs during the early 1940's.

The cause and effect relationship between abundant, high-quality forage and increased numbers of mule deer is widely accepted. Subjective evidence seems to support the premise, although there is little quantified data that the opening of dense forests by logging and fire resulted in improved forage conditions and increased deer populations.

A majority of mule deer habitats in the Intermountain West, particularly those comprising winter ranges, are situated on shrublands, or semiarid woodlands supporting juniper, pinyon pine (*Pinus* spp.), Douglas-fir, limber pine, or ponderosa pine. Large-scale commercial cutting took place at various locations during the period 1860 to 1900 in support of mining operations. A noteworthy example is central Nevada where great quantities of pinyon and juniper were cut to fuel kilns for processing ore and for other needs (Young and Budy 1979; Lanner 1981). Selective cutting for fencing, firewood, and lumber also took place in many localities in the Intermountain West. Careless ignitions often followed cutting operations. Where heavy cutting and fire took place, the disturbance provided a stimulus for regeneration of forage and cover. The absence of fire following disturbances in these ecosystems was an important factor in enhancement of forage and cover because it allowed plants to reach a productive age. Mule deer populations in these ecosystems did not peak until 30 to 70 years after disturbance.

In summary, hypothesis 2—conversion of coniferous forests to shrubs—can be substantiated for commercial forest types that were cut and burned or were swept by large wildfires after the turn of the century. Large-scale cutting of pinyon/juniper and selective cutting of other trees in numerous localities is also consistent with this hypothesis. Hypothesis 2 is not applicable to dry forests and shrublands of the Intermountain West where little or no cutting of conifers occurred because of their sparsity, or absence, or great distance from settlement. Because these lands comprised a large majority of early mule deer habitat, this hypothesis has limited applicability.

Hypothesis 3: Conservation Measures and Predator Control

Leopold and others (1947) concluded from a survey of overpopulated deer ranges in the United States that:

> Buck laws, predator control, and over-large refuges, working in combination to allow undue multiplication of breeding females, seem to be the predisposing causes of irruptive behavior.

At the turn of the century, mule deer population levels were so low that there was widespread support for conservation measures. Population reductions had been particularly heavy where large numbers of people were drawn by prospecting for gold. Homesteaders also exploited mule deer, hunting them yearlong, before the advent of game laws. Near some army outposts, heavy hunting contributed to mule deer exploitation.

After game laws were established in the latter 1800's, depletion of mule deer continued because of minimal enforcement. In Utah, a law in 1908 prohibited hunting of deer and other big game for 5 years (Rasmussen and Gaufin 1949). This step was followed by restrictive open seasons. Similar sequences of laws occurred in Nevada, Idaho, Montana, and Wyoming.

In the early 1900's, "the buck law" was enacted to protect breeding females. This regulation was in effect during the years of mule deer population increases and was rescinded in the 1950's after herds had reached peak levels. Exemption of does from hunting, either by buck laws or by large closed areas for considerable periods,

resulted in population irruptions (Leopold and others 1947).

During the first two or three decades of this century when deer herds were at low numbers, numerous game preserves were established to protect big game. By 1925, 11 preserves had been set up on some of the more favorable deer and elk ranges in Utah (Rasmussen and Gaufin 1949). Hunter and Yeager (1956) felt that game preserves were of vital significance in the reestablishment of herds in the western States.

Control of predators to protect livestock has also been identified as a predisposing cause of mule deer irruptions or population increases (Leopold and others 1947; Rasmussen and Gaufin 1949). It was reasoned that all western deer irruptions followed, and none preceded, the initiation of Federal predator control of the public lands in about 1910. These United States irruptions had coincided with greatly reduced predation by wolves (*Canis lupus*) and mountain lions (*Felis concolor*).

As Connolly (1978) discusses, some authors have discounted the premise that control of predators allowed mule deer to increase. They reasoned that, although substantial numbers of mule deer, especially fawns, are taken by predators, predation was not limiting to deer numbers. Caughley (1970) argued that habitat changes rather than predator control were probably responsible for population increases on the Kaibab Plateau in Arizona. Keith (1974) disagreed with this view by maintaining that predation could be a significant regulator of natural ungulate populations.

The relative effects of predation on mule deer populations may have varied regionally. Fish and game departments in Arizona and New Mexico have felt that predators offer definite limitations to herd increases, while departments in other States and Canadian Provinces concluded that predators have no basic influence on maintenance of mule deer numbers (Hunter and Yeager 1956).

There are numerous accounts of specific ungulate populations whose numbers or growth rates were thought to be limited by predation. But of 31 reports in North America summarized by Connolly (1978), only four refer to mule deer. In these cases, the coyote (*Canis latrans*) was either the sole predator or a copredator in combination with the bobcat (*Lynx rufus*). Salwasser (1976) reports that coyotes eat deer, and fawns in particular. High predation rates of coyotes on young fawns have been documented (Trainer 1975; Craiger and Cockle 1981). Also coyote control has resulted in increased fawn survival (McMichael 1970; Robinette and others 1977). Coyotes have accounted for significant losses of adult deer on some winter ranges (Richens 1967).

Although coyotes kill mule deer and have been reported to reduce populations in various localities, there is a question whether coyote predation has been instrumental in suppressing mule deer populations over broad areas. Wagner (1978) points out that deer increases in the West took place in the face of heavy coyote populations. Leopold and others (1947) discounted the coyote as an effective deer predator because many deer irruptions occurred in the presence of numerous coyotes. Salwasser (1976) believes that coyotes are a proximate factor behind fluctuations in the California-Nevada interstate mule deer herd.

In addressing the predation issue, Connolly (1978) concluded that because ungulate irruptions typically followed suppression of large predators concurrently with human modification of habitats, the relative roles of predator control and habitat modification in promoting ungulate irruptions cannot be assessed. To the contrary, I believe that there is sufficient information to rate the relative importance of predator control and habitat modification in mule deer irruptions.

There is widespread acceptance that ungulate populations are unalterably tied to habitat quality. Other factors being equal, poor habitats produce few animals, while quality habitats produce many animals. Evidence already presented in this paper suggests that many presettlement habitats had a low capacity for producing mule deer because of frequent fires. These relatively stable environments of low-carrying capacity were not capable of supporting high densities of mule deer. Following settlement in the mid- to late-1800's, mule deer habitats and populations were exploited and numbers were further depressed. The probability of mule deer populations irrupting on these marginal ranges as a result of predator control seems remote. As Hornocker (1976) points out from studying mountain lion predation:

> If suitable habitat is not available for prey species, then no amount of predator control will bring about flourishing populations of that prey species.

The bulk of evidence strongly suggests that mule deer increases in the Intermountain West were complemented by predator control. Predator control coincided with mule deer habitats that had been unintentionally enhanced by man's activities. Where there were relatively high numbers of predators to prey, predator removal would have allowed accelerated increases in mule deer.

The evidence does not support the contention that conservation measures and predator control were solely responsible for mule deer population increases. This conclusion overlooks the role of habitat in influencing populations. It seems evident that mule deer would not have been able to reach the levels achieved by the 1950's had habitat conditions remained at a low level of productivity, as was the situation before settlement. There seems to be little doubt that improved forage and cover resulted in widespread optimization of mule deer habitat. This not only allowed mule deer populations to increase on existing habitat, but to expand into areas that previously were poor habitat.

Hypothesis 4: Reduction in Livestock Numbers

Some authors have reported that establishment of grazing systems on livestock ranges and reduction of livestock numbers contributed to improved forage conditions for mule deer. They reason that improved forage conditions in conjunction with other factors allowed mule deer populations to increase (Rasmussen and Gaufin 1949; Salwasser 1976).

Before Euroamerican settlement, mule deer competed for forage with other native ungulates and small mammals. Differences in habitat preferences tended to separate populations, thereby minimizing interspecific competition.

The introduction of livestock into the Intermountain West in the 1860's resulted in unprecedented competition for forage. Wagner (1978) reports that sheep, not including lambs, in the 11 western States reached a level of nearly 20 million by 1895, and then varied between 20 and 30 million for the next 50 years. Turning stock onto spring ranges when plants were in the formative stages of development was particularly harmful and led to widespread destruction of vegetation. The practice of grazing sheep and cattle in common resulted in the overuse of forage species. Bunchgrasses were especially impacted. By the mid-1930's, the forage resource had been heavily depleted. The level of depletion varied latitudinally from moderate in northern Montana to severe in most of Nevada and Utah (Clapp 1936). In different parts of the West, grazing capacity for livestock in the early 1930's was estimated to be 60 to 90 percent less than in pioneer days (McArdle and Costello 1936). The sagebrush-grass type was particularly impacted by grazing. Marked increases in sagebrush were noted as a result of removal and weakening of grass competition.

After excessive domestic grazing during the late 1800's and early 1900's, mule deer populations began to increase in localized areas despite heavy use by livestock. Mule deer population irruptions were reported in parts of Nevada and Utah in the 1930's and in the mid-1940's in Idaho (Leopold and others 1947). Julander (1962) addressed the question of how large populations of mule deer could build up on depleted range in Utah. He concluded that a great increase in woody shrubs provided habitat that permitted an extremely high buildup of deer numbers. Because of increased browse production, population peaks were believed to be much higher than could have been reached on presettlement ranges.

Livestock reductions starting in the early 1920's were instrumental in providing more usable habitat for mule deer. Much of the improvement took place on National Forests which comprised a large segment of mule deer habitat in the West. Here, sheep numbers were reduced from more than 8 million in 1918 to about 2.5 million by 1960 (Wagner 1978). This marked reduction resulted in fewer sheep bands per allotment, thus allowing herders to graze sheep in more accessible areas while leaving the steeper slopes only lightly grazed or untouched. This increase in forage availability in mountain habitats was apparently favorable for mule deer population increases.

Cattle numbers in the 11 western States have steadily increased from about 3 million in 1870 to about 23.5 million in 1975 (Wagner 1978). Most of this increase, however, was due to a shift from open range to feedlots and private pastures. Cattle numbers on National Forests have not followed the same trend. Records show a decline from nearly 9 million in 1918 to about 5.3 million in 1973 (Wagner 1978). It would appear that this decline was favorable to deer, particularly in earlier years on ranges where stocking was great and competition was excessive.

Although there is less overlap between the diets of cattle and deer compared to sheep and deer, forage competition can result, particularly in arid regions where forage is limited (Gallizioli 1977). Conversion from sheep to cattle on many allotments since the early 1960's has tended to concentrate use on riparian areas and more gentle terrain that is important mule deer habitat. Longhurst and others (1981) suggest that this trend has been detrimental to mule deer because of increased competition for forage. This apparently has occurred in many localities. Conversely, benefits to mule deer also occurred on steeper terrain unsuitable to cattle use where the forage resource improved due to reduced grazing pressure by domestic livestock.

The combined evidence suggests that reductions in sheep grazing allowed increased availability of forage that complemented mule deer population increases. Conversion from sheep to cattle on public lands seems to have had a variable effect depending upon topography, water availability, and stocking rates. Overall the effect was positive because of less overlap in diets and a reduction in competition for forage on steeper terrain.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Of four hypotheses that may have favored mule deer population increases between the early 1930's and mid-1960's, the most likely is that successional changes in deer habitat were primarily responsible. Much evidence shows that woody plants preferred by mule deer markedly increased in mountain valleys and on slopes of the Intermountain West following settlement. Succession to shrubs and trees seems to have mainly resulted from livestock grazing and a marked decrease in fire occurrence. Conservation measures, predator control, and livestock reductions all complemented the habitat improvement that led to population increases.

Toward the end of the 20th century, the condition of mule deer habitats in the Intermountain West varies widely, depending upon site potential and the way they have been utilized and managed. But most have one thing in common—they show marked advances in the development of woody vegetation. Much of this change in recent years has been detrimental to mule deer populations, particularly on lands where heavy growth of trees has resulted in decline and loss of herbs and palatable shrubs. In areas where trees are not competitive, the shrub complement is dense and reaching old age, plant vigor is low, seedlings are few, and repeated insect defoliation and browsing have taken their toll.

Urban expansion onto mule deer habitat has, of course, been an increasing problem in recent years. This underscores the need to maintain productive deer ranges elsewhere.

Mule deer habitats reached optimum levels during and following a period of extreme disturbance by livestock grazing, logging, and fire. Considering the current approach to wildland management, it is unlikely that these lands will again be disturbed as extensively as they were formerly. Thus, mule deer habitats will continue to decline in both area and quality by loss to human development and successional advances. Nonetheless, there are large areas where mule deer will receive major consideration in resource management decision making. Here, there are opportunities to maintain productive habitats by management of livestock, application of prescribed fire, mechanical treatment, and cutting of trees depending on the situation.

Longhurst and others (1981) concluded that prescribed livestock grazing has more potential for improving deer habitat than any other land use practice. These researchers propose that greater efforts should be made to minimize the detrimental effects of grazing on deer habitat, and particularly to explore the possibility of using prescribed grazing to enhance forage quality. Research on utilizing prescribed grazing systems to improve deer and elk range quality on sagebrush/grass ranges has been underway in northwestern Utah over the past 25 years (Urness 1981). This effort has demonstrated the potential for manipulating livestock grazing in ways to directly improve habitat values for big game. The applicability of this research on western ranges has its limitations, however, because permitees have little flexibility in adjusting grazing patterns that allow enhancement of wildlife habitat values.

Manipulation of livestock grazing alone would not be sufficient to rehabilitate deteriorated mule deer habitats. Although the historical evidence demonstrates that livestock grazing was important in improvement of post-1900 mule deer habitats, this disturbance occurred on habitats that were in early succession following past fire disturbance. Today, most mule deer habitats are in a state of advanced succession, and thus have a markedly reduced ability to respond to the manipulation of livestock grazing only. Successional advances in many regions, particularly those invaded by conifers, will require removal of trees by cutting or fire in combination or separately to return habitats to a productive condition. Priority vegetal types on mule deer ranges in the Intermountain West include mountain shrub, sagebrush/grass, pinyon/juniper, ponderosa pine, and Douglas-fir.

Over the past 40 years, experimentation and application of prescribed fire have demonstrated that, properly applied, fire can result in an improvement of mule deer habitat. Nevertheless, the art of applying prescribed fire is a major challenge in resource management. Whether or not to use fire largely depends upon the potential of the site to respond to fire. A wide range of plant responses are possible. Important considerations are preburn plant composition, fuel type, fire severity, burn size, and postburn foraging intensity. Following fire, it may take 20 years or more to realize optimum deer habitat. Fire sets plant succession back to early seral stages that are less productive of mule deer. As succession advances, however, these habitats become prime producers of mule deer.

The case for utilizing prescribed fire is supported by a trend toward increased numbers and size of wildfires, particularly in woodlands where there has been an enormous increase in living fuels. In semiarid regions of the Intermountain West, long-term fuel buildup is resulting in uncharacteristically severe wildfires, followed by very slow vegetal recovery. These fires are more severe than they were previously because of the marked increase in woody fuels. This undesirable trend will continue and may accelerate in the future, unless fuels are substantially reduced.

There is widespread opportunity to break up fuel continuity and produce mosaics that will not only benefit mule deer, but reduce the likelihood of extensive wildfires. In grasslands that have been invaded by conifers, there is potential for cutting living trees for firewood and other purposes followed by prescribed fire. Use of moderate-intensity prescriptions in plant communities such as sagebrush/grass, aspen, and mountain shrub (*Ceanothus* spp., Scouler's willow (*Salix scoulerana*), serviceberry, chokecherry, mountain maple, Gambel oak, etc.) would result in nutrient increases, increased palatability, and increased forage availability. Surface fires of moderate intensity, after thinning or selective cutting, have good potential for improving mule deer habitat in ponderosa pine and Douglas-fir forests. Not only does fire promote regeneration of crown-sprouting shrubs, but it also bares mineral soil that allows establishment of herbs and shrub seedlings such as bitterbrush and mountain-mahogany. Application of surface fire is also compatible for silviculture, as ponderosa pine regeneration is favored over the less valuable Douglas-fir.

The future of maintaining productive mule deer habitats in the Intermountain West lies in purposeful disturbance—not protection from perturbations. The objective in managing perturbations for improved mule deer habitat should be to achieve a mosaic of seral stages on a given deer range, rather than taking no action which results in vast expanses in mostly advanced successional stages.

The only practical and acceptable ways of perpetuating productive mule deer habitats are by management of livestock, mechanical treatment, cutting of trees, and use of prescribed fire. The appropriateness of these approaches will depend upon local vegetal conditions, administrative constraints, and public attitudes. Mule deer habitats cannot be brought back to earlier productive conditions that occurred throughout the West. There is, however, much opportunity to rejuvenate mule deer habitats in priority areas.

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APPENDIX 1: PRE-1900 REPORTS OF MULE DEER IN MONTANA, WYOMING, UTAH, IDAHO, AND NEVADA

Reference	Observer	Date	Location	Observations
			Montana	
Thwaites 1959	Lewis & Clark	1805-06	Missouri River	Mule deer common up Missouri River to Gates of the Mountain. Uncommon in southwestern and west-central Montana except for some localities where they may have been common.
Phillips 1940	Ferris	September 1832	Southwestern Montana	Journal suggests local abundance on what may have been the Boulder drainage.
Lewis and Phillips 1923	Work	Winter 1832	Western and Southwestern Montana	Journal suggests scarcity of mule deer on Blackfoot, upper Clark Fork, and Beaverhead drainages.
Montana Historical Society 1902	J. Stuart	April 1863	Madison, Gallatin, and Yellowstone watersheds	Mule deer apparently uncommon west of Gallatin Valley; more common to the east.
Mullan 1855	Mullan	December 1863	Southwest Montana	Observed large bands of white-tailed and "black-tailed" deer at Lower Blacktail Deer Creek near site of Dillon, MT.
Hafen and Hafen 1961	Sawyers	1865	Southeastern Montana	Reported game including deer abounded on the Little Big Horn drainage.
Ludlow 1876	Ludlow	1875	Southwestern Montana	Reported elk and deer to be numerous in the vicinity of Bridger Pass in Bridger Mountains.
			Wyoming	
Thwaites 1966b	Palmer	June 1846	Southeastern Wyoming	Mule deer were apparently plentiful on the North Fork of the Platte River.
Hafen and Hafen 1961	Rockafellow	August 1865	Central Wyoming	Observed a group of blacktailed deer while crossing the Pumpkin Buttes.

Doane 1877	Doane	December 1876	West-central Wyoming	No deer seen on trip down Snake River between Jackson and Alpine.
Endlich 1879	Endlich	1877	Southwest and south-central Wyoming	Reported mule deer to be plentiful on west slope of Wind River Range and quite abundant in some localities along the Sweetwater and Seminole Hills.
Lott 1940	Wise	September 1880	North-central Wyoming	Killed several nice bucks on east slope of Big Horn Mountains.
			Idaho	
Spaulding 1956	Ross	November 1823	Central Idaho	Deer numerous on Salmon River below Stanley.
Rich 1950	Ogden	June 1826	Southwest Idaho	Deer scarce year long between Wood River, ID, and Burnt River in eastern Oregon.
Lewis and Phillips 1923	Work	April 1832	East-central Idaho	Journal suggests deer scarcity on Salmon River between mouth of Pahsimori River and present-day Challis, ID.
Lewis and Phillips 1923	Work	June 1832	Southwest Idaho	On middle fork of Payette River party was forced to kill horses for food. Old tracks indicated that deer were numerous earlier.
Thwaites 1966a	Townsend	July 1833	Southeast Idaho	Game scarce in Soda Springs locality.
Thwaites 1966a	Townsend	August 1833	South-central Idaho	Mule deer numerous on upper Lost River.
F. Wislizenus 1912	Wislizenus	July 1839	Southeast Idaho	Soda Springs locality did not abound in game. Game scarce in Blackfoot Mountains.
Phillips 1957	G. Stuart	1858	Southeast Idaho	Game scarce between Fort Hall and Fort Bridger.
Thompson and Thompson 1982	Leigh	1876	Southeast Idaho	Deer uncommon in Snake River drainage east of present-day Idaho Falls.
			Utah	
Anonymous 1946	Escalante	1776	Utah	Party killed buffalo, traded with Indians for bighorn sheep meat, but no mention of deer in what is now Utah.

APPENDIX 1. (Con.)

Reference	Observer	Date	Location	Observations
Anonymous 1946	Smith	1826-27	Northern Utah	These trappers described the occurrence of buffalo, antelope, elk, and incidental deer. Utah area generally did not have abundant game. Indians depended mainly on insects, seeds, fruits, and small animals as sources of food.
	Ferris	1830-34	Northern Utah	
	Walker	1833-34	Northern Utah	
	Russell	1834-40	Northern Utah	
W. Egan 1917	H. Egan	1847	Northern Utah	Reported game to be scarce on west slope of the Wasatch Mountains.
Stansbury 1852	Stansbury	1847-48	Northern Utah	Game very scarce in Salt Lake valley during winter of 1847-48.
			Nevada	
Rich 1950	Ogden	May 1826	Northeastern Nevada	Hunters in quest of deer in upper Bruneau River watershed returned without success. No tracks were seen.
Williams 1971	Ogden	December 1828	Northeast Nevada	No deer observed during 8-day trip east which included crossing of Toana and Pequop Mountain's deer winter ranges.
Williams 1971	Ogden	April-June 1829	Northeast and north-central Nevada	Return trip. No deer were seen despite numerous hunting excursions by most experienced hunters. Country covered included parts of Independence, Bull Run, and Santa Rosa Ranges.
Haines 1971	Work	May-June 1831	Northeast Nevada	No deer seen from May 24 to June 27 between what is now Deeth and McDermit, NV. Route of travel included Marys River, Charleston, Wildhorse Reservoir, Independence Valley, Humboldt River, and west side of Santa Rosa Range.
Fremont 1887	Fremont	January 1844	Western Nevada	Tracks in one locality suggests deer may have been numerous in some areas along the east slope of the Sierra Nevada during periods of winter concentrations.
Simpson 1876	Simpson	1859	Eastern and central Nevada	No deer were seen during a round-trip wagon road survey between Camp Floyd, UT, and Genoa, NV.

APPENDIX 2: HISTORICAL ACCOUNTS OF VEGETAL CONDITIONS ON PLAINS AND BROAD SEMIARID VALLEYS

Reference	Observer	Date	Location	Observations
			Montana	
Raynolds 1868	Raynolds	July 1859	Powder River	"Our route lay now down the valley of Powder River, which was covered with large sage bushes . . . ." "The grass on the river surpassed our expectations in its quality . . . ." "The eye grows weary of the constant sight of barren hills and blue sage."
Raynolds 1868	Raynolds	August 1859	Lower Rosebud Creek	"The entire river bottom is covered with sage . . . ."
Raynolds 1868	Raynolds	August 1859	Lower Bighorn River	"Artemisia covered the ground over which we traveled to-day, seriously inconveniencing the progress of our vehicles."
Raynolds 1868	Raynolds	August 1859	Hardin, Montana	". . . we found fine grass, the best seen this season, but it does not extend over one-fourth of a mile from the river, the balance of the valley being clay covered with the interminable artemisia."
Ludlow 1876	Ludlow	August 8, 1875	16 Mile Creek (S. of Smith Valley)	". . . the road beyond lay over a dry, yellow, gently undulating prairie, which . . . became an interminable waste of sagebrush."
Ludlow 1876	Ludlow	September 1875	Big and Little Timber Creeks, Yellowstone R.	"The country between these two streams is very poor, almost no grazing; sagebrush being the main production."
			Wyoming	
Thwaites 1966b	Palmer	July 1845	North Fork Platte River to Green River	Described vegetation as predominantly sagebrush. Hills and moist areas were grassy.

(con.)

APPENDIX 2. (Con.)

Reference	Observer	Date	Location	Observations
Raynolds 1868	Raynolds	October 1859	South of Sheridan	"Following up the valley of Powder River we found our progress impeded by high sage and deep ravines . . . ."
Raynolds 1868	Raynolds	October 1859	Upper Powder River	". . . a very thin growth of bunchgrass upon some of the ridges, and the never-failing sage (Artemisia) completes the vegetation."
Raynolds 1868	Raynolds	May 1860	North of Rattlesnake Hills	"The country passed over was a gently rolling plateau, with no obstructions save the sage, which embarrassed the heavy wagons of the escort."
Endlich 1879	Endlich	August 1877	Jeffery City locality, Sweetwater River	"Emerging from this narrow place we see before us a wide, meadow-like flat, covered with excellent grass."
Endlich 1879	Endlich	August 1877	West of Rawlins	"The country here is very barren, being covered with sagebrush and prickly pears."
Endlich 1879	Endlich	September 1877	Crook's Gap near Green Mountains	"A long ride through sagebrush, over a sterile country, brought us to this pass."
Endlich 1879	Endlich		Sweetwater region vegetative summary	"Reaching the bluff country, we find sagebrush (Artemisia tridentata) very prevalent. Its appearance usually indicates a dry, sandy region." "All the low country lying east of the Wind River Mountains and north of the Sweetwater Plateau contains sagebrush and cactus (Opuntia)." "On the Sweetwater Plateau but very little timber occurs, excepting on its north slope. There pines and quaking asp are found in the gulches, while sage covers the intervening ridges. On the southern slope of the plateau bunchgrass (Eriocoma cuspidata) is abundant, affording good feed for the animals."

Idaho

Rollins 1935	Stuart	September 1812	American Falls	"The country pafsed [passed] since yesterday morning has improved greatly--the sage and its detested relations gradually decreased, and the soil though parched, produces fodder in abundance . . . ."
Haines 1971	Work	December 1830	Snake River Plains S. of Atomic City	". . . the country still maintains the same appearance except one portion of the plain which we passed which is clear of wormwood [sagebrush] and has some course grass peeping above the snow."
Haines 1971	Work	February 7, 1831	Below outlet of Portneuf R.	". . . was deterred from doing so by being told that the grass had been burnt in the fall by the Indians."
L. McKinstry 1975	B. McKinstry	July 1852	Snake River Plains	"Beyond Snake River the whole country is an elevated sage plain."
L. McKinstry 1975	B. McKinstry	August 1852	South of City of Rocks	". . . by an easy ascent reached a summit and as gradually descended to a valley of sage and sand . . . ."
Mullan 1855	Mullan	December 1852	Snake River Plains	"Our trail crossing the Medicine Lodge Creek led through an immense sage prairie, extending about twenty miles to the north, to the Snake River on the south, and to the Tetons in the east."
Bradley 1873	Bradley	July 1872	Snake River Plains	". . . we see the rough, almost impassible, basalt-plain, thickly overgrown with sagebrush, stretching away toward Market Lake [Mud Lake]."
Bradley 1873	Bradley	July 1872	Upper Snake River Plains-Rexburg locality	"The low plain bordering Henry's Fork on the west is from two to eight or ten miles in width, partly well grassed, though with many dense patches of sagebrush."
Bradley 1873	Bradley	July 1872	Upper Snake River Plains-NE of St. Anthony	"The abundant growth of grasses, sedges, and other flowering herbs shows plainly that only slight irrigation would be necessary to make this valuable farming-land . . . ."
			Utah	
Cottam 1947	Father Escalante	1776	Utah Lake	Father Escalante speaks of grass on plains having burned. Cottam concludes that grass, sufficient to carry prairie fire, must have been fairly abundant.

(con.)

APPENDIX 2. (Con.)

Reference	Observer	Date	Location	Observations
Stewart 1941	J. Mathews J. Brown	July 1847	Salt Lake Valley	Crossed valley to westside and reported that the wild sage is very plentiful--showing the land is not as rich as along the Wasatch front.
Christensen and Johnson 1964	Farrer	October 1849	Round and Pavaunt Valleys	". . . we came into a large wide Canion feed growing very luxuriantly. We came into an extensive valley little water sage Brush plentiful feed prety good . . . ." ". . . crossed another wider creek a little timber growing on it. traveled thro a good deal of Sage . . . ."
Christensen and Johnson 1964	Smith	December 1850	Round Valley	"Camped in a beautiful valley. Snow 12 inches deep. Good feed, bunchgrass, plenty sage brush . . . ."
Christensen and Johnson 1964	Beckwith	October 1853	NW of Holden	". . . this whole valley, some fifty or sixty miles in diameter, is one vast artemisia plain surrounded by grassy mountains."
			Nevada	
Simpson 1876	Simpson	May 1859	Steptoe Valley	"This is a poor, arid valley, perfectly useless for cultivation where we cross it . . . . further, south . . . . there is a great deal of good, available pastural and cultivatable soil."
Simpson 1876	Simpson	May 1859	Huntington Valley	"As usual the artemisia covers the valley and in this locality is quite rank in growth."
Simpson 1876	Simpson	May 1859	Valley north of Roberts Creek	"Soils argillaceous and covered with sage and greasewood."
Simpson 1876	Simpson	May 1859	Big Smoky Valley	"Soil areno-agrillaceous, and is very thinly covered with artemisia."

Simpson 1876	Simpson	May 1859	Reese River Valley	"The grass along it [Reese River] is luxurient, but in many places alkaline. It is best and very abundant farther up the stream, and extends as far as the eye can reach . . . . Soil argillo arenaceous and covered with wildsage and greasewood."
Beckwith 1855	Beckwith	1855	Humboldt River	"The valley of the Humboldt is more or less covered with the several varieties of artemisia, which occupy so large a proportion--at least nine-tenths of the plains--of our territory between the Rocky and Sierra Nevada Mountains, and characterize its vegetation."

APPENDIX 3: HISTORICAL ACCOUNTS OF VEGETAL CONDITIONS ON MOUNTAIN VALLEYS AND SLOPES

Reference	Observer	Date	Location	Observations
			Montana	
Haines 1965	Russell	September 1835	Ruby Range	"Traveled about 18 miles over high rolling hills beautifully clothed with bunchgrass."
Mullan 1855	Mullan	December 1853	Bitterroot Valley	"The soil of this portion of the valley is principally of a rich dark-colored loam . . . the whole being covered with a growth of rich and luxurant grass."
Mullan 1855	Mullan	December 1853	Horse Prairie, Red Butte	"Our course during the earlier part of this day . . . lay over a series of low sandy ridges, covered with the artemisia, growing from three to four feet high."
Mullan 1855	Mullan	December 1853	Red Rock Creek	"We found the soil of this valley principally of a yellowish or grayish yellow colored clay, upon which through-out its whole length, the wild sage grows in the greatest abundance. On the lower and the upper portions of this valley we found the grass to be exceedingly rich, but near the middle nothing growing save the wild sage bushes."
Mullan 1855	Mullan	December 1953	Melrose Valley	"The grass of the valley we found to be very good. The soil, however, is poor, being principally a yellowish clay, that bakes in the sun.
Phillips 1957	Stuart	October 1857	Monida Pass	"Instead of the gray sagebrush covered plains of Snake River, we saw smooth rounded hills and sloping bench land covered with yellow bunchgrass that waved in the wind like a field of grain."
Raynolds 1868	Raynolds	September 1859	Southeast Montana	Reported extensive grasslands in the upper watersheds of the Little Big Horn, Rosebud, and Tongue Rivers.
Raynolds 1868	Raynolds	July 1860	Little Belt Mountains and Smith Valley	"The grass through which we have passed to-day has been unequalled in luxuriance and richness, surpassing the fertile meadows of eastern farms."

Hayden 1873	Hayden	1872	Horse Prairie	". . . the soil is fertile, and during the summer season the grass is excellent . . . ."
Hayden 1873	Bradley	1872	Upper Madison River	". . . the volcanic sand being only sparsely covered with a growth of course plants, often including much sagebrush."
Hayden 1872	Hayden	1871	Raynold's Pass	"The Low or Raynold's Pass is like a lawn--smooth and covered with grass . . . ."
Hayden 1872	Hayden	1871	Upper Madison River	" . . . on both the east and west branches, which enter the Madison near together at this point, the surface is covered with a luxuriant growth of grass . . . . The slopes from the base of the mountains on either side down to the river are most admirable illustrations of lawns on a grandscale."
Ludlow 1876	Ludlow	August 8, 1875	Bridger Pass Bridger Mountains	"Grass is abundant, even among the timber . . . ."
			Wyoming	
Thwaites 1966b	Palmer	1845	Cokeville region	"The hills bordering on Bear River on this days travel are very high and rugged; they are covered with grass."
Raynolds 1868	Raynolds	June 8, 1860	Upper Gros Ventre River	". . . grass has become abundant, while flowers surround use on every side."
Montana Historical Society 1902	DeLacy	August 25, 1863	Jackson Hole (lower Antelope Flats)	"It is covered with fine grass; the soil is deep in many places . . . ."
			(upper Antelope Flats)	"In the evening we took a northwest course toward the river, passing over a plain, part of which was covered by the largest and thickest sage-brush that I had ever seen."
Montana Historical Society 1902	Stuart	May 26, 1863	Wind and Popo Agie Rivers	"Plenty of cottonwood along the river, and gravelly, greasewood, and sagebrush plains . . . . Abundance of bunch-grass in the hills, but very little of any kind along the river."

(con.)

APPENDIX 3. (Con.)

Reference	Observer	Date	Location	Observations
Jones 1875	Jones	June 27, 1873	East slope of Wind River Mountains	"The long slopes of the foothills of the mountains are here covered with a spendid growth of grass . . . ."
				"The country is rolling, with a good soil, supporting a fine growth of grass, but no trees."
Jones 1875	Jones	July 17, 1873	Middle Fork Owl Creek trib. to Bighorn River	"The mountain-slopes are generally rounded, and covered with a fine growth of grass. . . ."
Jones 1875	Jones	July 21, 1873	Cottonwood Creek	"The line of march lay through the grassy and well watered foothills of the mountains."
Jones 1875	Jones	July 22, 1873	Gooseberry Creek	"The country is still high-rolling, with fine grass all over it, and a few trees."
Endlich 1879	Endlich	1877	Sweetwater Plateau	"On the southern slope of the plateau bunchgrass (Eriocoma cuspidata) is abundant . . . ."
			Idaho	
Fremont 1887	Fremont	1843	Malad Summit	"In the afternoon we entered a long ravine leading to a pass in the dividing ridge between the waters of Bear River and the Snake River . . . our way being very much impeded, and almost entirely blocked up, by compact fields of luxurient artemisia."
				"All the mountain sides here are covered with a valuable nutritious grass, called bunchgrass . . . ."
Thwaites 1966b	Palmer	1845	Mountain Home locality	". . . we directed our course up a stony hill; thence over a sage plain to a spring branch . . . in general, the mountains here are covered with grass . . . ."
Stansbury 1852	Stansbury	September 22, 1849	Lava Hot Springs locality	"From the top of the bluff, an extensive level plain, clothed with grass, is spread out before us like a beautiful picture . . . ."

Raynolds 1868	Raynolds	June 25, 1860	Henry's Lake	"The prairie was beautiful with its luxurient growth of young grass, and bands of antelope were scattered about us on all sides."
Hayden 1872	Hayden	1871	Henry's Lake	"Henry's Lake was at our feet . . . . To the west there is a beautiful grassy valley . . . ." "Far southward extends the valley of Henry's Fork . . . . The upper portion, for an extent of twenty to twenty-five miles in length and five to ten miles in bredth, is like a meadow, covered with a luxarient growth of grass . . . ."
Bradley 1873	Bradley	1872	Teton Basin	"Most of the plain is thickly covered with a luxurient growth of grasses and other good forage plants, though some small areas are sandy and comparatively barren."
Hayden 1873	Hayden	1872	Pocatello	"Fort Hall is a small but exceedingly neat post . . . and is located in a beautiful fertile grassy valley, among the foothills on the east side of the Snake River Basin . . . ."
Hayden 1873	Hayden	June 1872	Pleasant Valley	". . . as we approach Pleasant Valley the hills are covered with a drift deposit . . . . These hills are covered over with grass."
Hayden 1873	Hayden	June 1872	Monida Pass region	"On the morning of June 29, we left the beautiful valley behind us and traveled 9 miles north . . . for ten or fifteen miles, the rounded, grass covered hills prevailed . . . ."
Thomas 1873	Thomas	1872	Blackfoot-Shelley region	". . . gazing from the summit of this ridge on the endless succession of the smooth, grassy ridges . . . ."
Thompson and Thompson 1982	Leigh	August 24, 1876	Rexburg-Canyon Creek region	"Reached Canyon Creek at 11 o'clock after a 15 mile ride over flat rolling country covered with excellent grass and free of sage."
St. John 1879	St. John	1877	Taylor Mountain	"The wolverine opens out into a beautiful little mountain basin . . . on the north undulating grass-covered slopes interspersed with groves of aspen . . . ."

(con.)

APPENDIX 3. (Con.)

Reference	Observer	Date	Location	Observations
St. John 1879	St. John	1677	Antelope Flat-SE of Ririe	". . . northward it is continued in a lower and narrower ridge, which finally expands into a plateau overlooking the grassy upland on the borders of the Snake plain."
			Utah	
Hull and Hull 1974	Ferris	1832	Cache Valley	"One of the most extensive and beautiful valleys of the Rocky Mountain Range . . ., producing everywhere most excellent grass . . . ."
Fremont 1887	Fremont	1843	Spanish Fork	"The streams are prettily and variously wooded, and everywhere the mountain shows grass and timber."
Fremont 1887	Fremont	1844	Mountain Meadows	"We found here an extensive Mountain Meadow, rich in bunch-grass and fresh with numerous springs . . . . The meadow was about a mile wide, and some ten miles long, bordered by grassy hills and mountains."
Cottam 1947	Bryant	July 30, 1846	Davis County to Beck's Hot Springs	Described the slopes as grassy along the Wasatch Front.
Cottam 1947	Gunnison	1849	Salt Lake Valley	"The valleys afford perennial pasturage, but the hillsides furnish bunchgrass only during the warm months of the year."
Cottam 1947	Stansbury	November 1849	Tooele Valley	"The grass is very abundant and numerous springs are found on both sides of [the valley]."
Cottam 1947	DeLaMare	1850's 1860's	Tooele Valley	On arriving as a boy, Mr. DeLaMare remembered a valley full of high waving grass.
Cottam 1947	Pratt	April 14, 1857	Mountain Meadows	"Some thousand or fifteen hundred acres of bottom or meadow lands were spread out before us like a green carpet richly clothed with a variety of grasses . . . . The surrounding hills are abrupt . . . and everywhere richly clothed with the choicest kind of bunchgrass . . . ."

Kern 1876	Kern	1845	Secret Pass	"The stream, after winding among the grass-covered hills, emerges into a plain . . . ."
Kern 1876	Kern	1845	Emigrant Pass	"Ascending some grassy hills, encamped at several springs. Bunch-grass plenty . . . ."
Utah Historical Society 1932	Bigler	1848	Wells	"The surrounding country looks beautiful with low mountains all around with plenty of grass."
Simpson 1876	Simpson	May 1859	Egan Mountains	". . . on the mountain-sides and in the ravines is to be found a great deal of grass."
				". . . we reached the mouth of Egan Canon, down which a fine, rapidstream runs, and on which we camped. Grass on the side of the mountain."
Simpson 1876	Simpson	May 1859	Diamond Mountains	"Grass along the stream, and plenty higher up on slopes of the mountains."
Simpson 1876	Simpson	May 1859	North end Monitor Range	"In 4.3 miles, cross Saw-wid Creek, a rapid stream . . . . Fine grass on it toward the mountains."
				". . . in the canyons higher up in the mountains, is plenty of grass."
Simpson 1876	Simpson	May 1859	Simpson Park Range	"The mountain-range immediately to our west is called by the Indians the Pah-re-ah or Water Mountain, on account of the many streams which flow down its sides into Kobah Valley, and on them is to be seen an abundance of grass."
Simpson 1876	Simpson	May 1859	Willow Creek-Simpson Park Range	"There is a great deal of meadow along it and bunchgrass on the sides of the mountains . . . ."
Simpson 1876	Simpson	May 1859	Reese River Valley	"The grass along it is luxuriant, but in many places alkaline. It is best and very abundant farther up the stream, and extends as far as the eye can reach."
Simpson 1876	Simpson	July 1859	Toiyabe Mountains	"The grass in Reese Valley, through the canons we have passed to-day, as well as everywhere nearly on the mountains, very abundant; more so than when we passed before."

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Gruell, George E. Post-1900 mule deer irruptions in the Intermountain West: principal cause and influences. General Technical Report INT-206. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 37 p.

Tests hypotheses for mule deer population increases between the early 1930's and mid-1960's. Concludes that livestock grazing and absence of fire converted vast areas of grasses and forbs to woody plants favored by mule deer. Mule deer populations, therefore, irrupted between 1930 and 1965 and have since experienced a decline as plant succession moves toward shrub senescence and trees. Habitat management alternatives are discussed.

KEYWORDS: mule deer, livestock, fire, grass, shrubs

INTERMOUNTAIN RESEARCH STATION

The Intermountain Research Station provides scientific knowledge and technology to improve management, protection, and use of the forests and rangelands of the Intermountain West. Research is designed to meet the needs of National Forest managers, Federal and State agencies, industry, academic institutions, public and private organizations, and individuals. Results of research are made available through publications, symposia, workshops, training sessions, and personal contacts.

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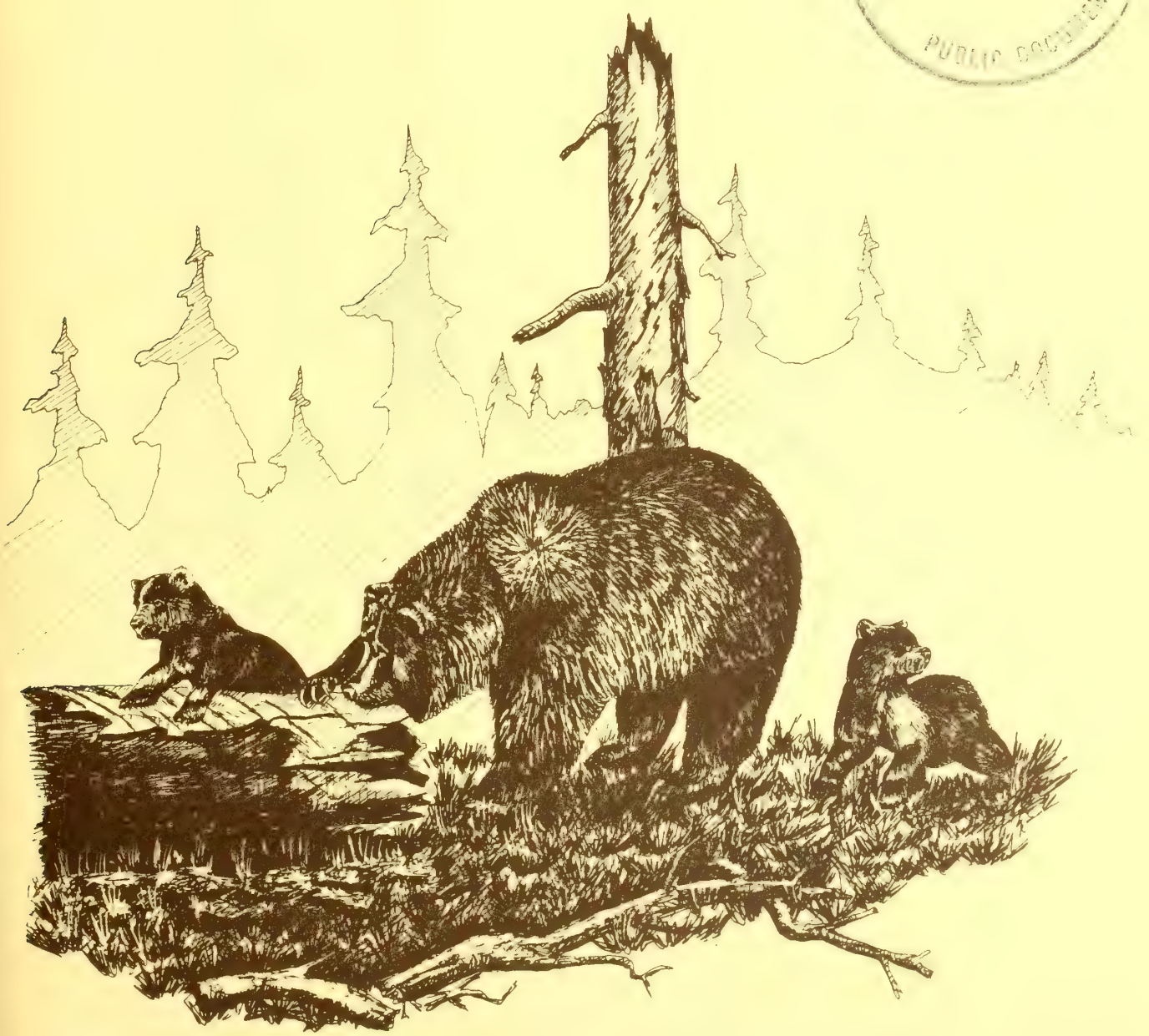
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Proceedings—Grizzly Bear Habitat Symposium

Missoula, Montana, April 30—May 2, 1985

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FOREWORD

The grizzly bear (Ursus arctos horribilis) once ranged throughout most of the Western United States. Excessive mortality and loss of suitable habitat resulted in a significant decline in the distribution and abundance of the grizzly. Today, an estimated 750 to 1,000 grizzlies occur in portions of Montana, Wyoming, Idaho, and Washington. This represents about 1 percent of the bear's historical range, and also about 1 percent of its original range. The Interagency Grizzly Bear Committee (IGBC), established in 1983, plays a major role in the conservation and management of the grizzly. The IGBC is composed of Regional Directors of the Fish and Wildlife Service and National Park Service, three Forest Service Regional Foresters, Montana State Director of the Bureau of Land Management, and State wildlife agency directors or representatives from the States of Idaho, Montana, Washington, and Wyoming. The primary objective of the IGBC is to serve as the coordinating mechanism for research and management related to grizzly bear in the lower 48 States.

The IGBC sponsored this symposium with the Center for Continuing Education and the School of Forestry, University of Montana. The symposium was presented by the Forest Service (Northern, Rocky Mountain, Intermountain, and Pacific Northwest Regions), and the Intermountain and Rocky Mountain Research Stations. It represents the first time a major effort has been directed specifically to grizzly bear habitat management. These proceedings are intended to provide scientists, educators, managers, and the interested public with the most advanced knowledge and technology regarding grizzly bear-habitat interrelationships.

The following individuals contributed significantly to the development and presentation of the symposium:

Program Committee: Glen Contreras, Chairman, Forest Service, Intermountain Region
Bob Gale, Forest Service, Siuslaw National Forest
L. Jack Lyon, Forest Service, Intermountain Station
Christopher Servheen, Fish and Wildlife Service
Lorin Ward, Forest Service, Rocky Mountain Station
Dale Wills, Forest Service, Rocky Mountain Region

General Manager: Gerry T. Baertsch, University of Montana

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Dr. Fred Lindzey, Fish and Wildlife Service
Dr. Christopher Servheen, Fish and Wildlife Service
Dr. David Winn, Forest Service, Intermountain Region
Dr. Pete Zager, Idaho Department of Fish and Game

Approximately 350 participants from land management agencies, industry, colleges and universities, and Federal and State research organizations attended.

It is hoped that the information contained within these proceedings will enlighten all of us to a better understanding of habitat management for the grizzly and enhance our appreciation for coexistence with the "great bear."

Stan Tixier

STAN TIXIER
Symposium General Chairman
1986-87 Chairman IGBC

Proceedings—Grizzly Bear Habitat Symposium

Missoula, Montana, April 30—May 2, 1985

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Session I—Habitat Concerns

Chaired by:

Barbara O. Holder, Director, Wildlife and Fisheries, Northern Region, Forest Service, Missoula, MT

Pete Zager, Regional Wildlife Biologist, Idaho Department of Fish and Game, Coeur d'Alene, ID

MANAGING POLITICAL HABITAT FOR GRIZZLY BEAR RECOVERY

John E. Burns

ABSTRACT: Although the level of scientific knowledge about grizzly bears and their habitat has significantly advanced in recent years, the application of that knowledge by management agencies has not consistently followed a holistic strategy incorporating human needs, grizzly needs, and political realities. As a result, recovery of the grizzly has been controversial, opposition to management practices has occurred, and political involvement is intensifying. In some instances, managers and key public and political figures disagree about biological questions. For the most part, however, the conflicts and controversy stem from the perceived exclusion of human needs and values by administrators. In a natural resource question so complex as the grizzly, unanimity cannot realistically be expected; however, if grizzly recovery is to be achieved, researchers and managers must develop broad support for a total management strategy based on human as well as bear needs.

DISTRIBUTION AND MANAGEMENT

Historic and Current Distribution

Although grizzly bears roamed throughout the Western United States early in the last century, only six areas in the conterminous 48 States supported self-perpetuating or remnant populations of grizzlies by the time the Grizzly Bear Recovery Plan was prepared in 1982 (U.S. Department of the Interior 1982).

The six areas vary considerably in topographic, climatic, and vegetative characteristics, as well as habitat capabilities and apparent bear densities. The largest populations are found in the northern Continental Divide grizzly bear ecosystem (NCDGBE) and the Yellowstone grizzly bear ecosystem (YGBE). Estimates of bear density are some three times greater in the NCDGBE, although the areas of occupied habitat are roughly equal in size. The other grizzly ecosystems--north Cascade, Silkirks, Cabinet-Yaak, and Selway-Bitterroot--are smaller and contain limited or remnant populations (U.S. Department of the Interior 1982).

Geopolitical Habitat Distribution

All of the grizzly bear ecosystems (GBE's) are within the States of Washington, Idaho, Montana, and Wyoming, and encompass portions of numerous National Forests, several National Parks, State lands, U.S. Department of the Interior, Bureau of Land Management administered public domain lands, and private lands. Rural and incorporated communities are within, surrounded by, or adjacent to grizzly habitat. The Yellowstone GBE is perhaps the most geopolitically complex, with parts of the occupied habitat in three States, two National Parks, five National Forests, State lands, BLM lands, and multiple counties. Several towns and rural communities are within or close to occupied habitat, as are privately owned ranch, recreational, and resort lands.

Recovery Plan and Management Guidelines

Management and research efforts have focused on the animals, their habitat, and the effects of human activities and natural resource use on both. The recovery plan provides an overall framework for managers, and ecosystem-localized guidelines have been adopted or are being prepared. These guidelines, such as the Guidelines for Management Involving Grizzly Bears in the Greater Yellowstone Area (Yellowstone Guidelines) adopted in December 1979, provide refined guidance for managers weighing alternative courses of action in grizzly habitat (U.S. Department of

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Agriculture 1979). The Yellowstone guidelines also provide a framework for responding to occasional situations such as "problem bears." Site-specific guidance is also provided, as in the Targhee National Forest Draft Land Management Plan, which incorporates the Yellowstone Guidelines as basic management direction and further refines those guidelines with site-specific direction for subunits of the Forest's management areas (Orme and Williams in preparation; U.S. Department of Agriculture 1981).

THE YELLOWSTONE GRIZZLY BEAR ECOSYSTEM

Management Direction and Public Perceptions

Occupied grizzly habitat in the Yellowstone region encompasses 5.5 million acres, mostly within the Shoshone, Bridger-Teton, Targhee, Gallatin, and Custer National Forests and Yellowstone and Grand Teton National Parks. The habitat is stratified by situations (I through V) in accordance with the Yellowstone Guidelines (U.S. Department of Agriculture 1979). The habitat stratification was implemented after the guidelines were adopted in 1979 and for several years was considered set. Neither the guidelines nor the situation stratification was subject to the National Environmental Protection Act (NEPA) process, nor were nonagency publics urged to participate to any significant degree, a fact which recently has politically clouded the legal status of the guidelines.

Concerns about Yellowstone grizzly management followed close on the heels of park tourism. In fact, early visitors such as Theodore Roosevelt commented on the problems associated with bear use of hotel garbage dumps in the Park. So strong is the relationship between bears and garbage that debate on current bear management practices often alludes to the closure of the Yellowstone dumps (Hackett 1983; National Park Advisory Board 1985). The ripple effect of the action to eliminate the bears' dependency on human foods extends throughout bear habitat far beyond the Park boundaries. In the view of some, such as sheep rancher Bill Enget, dump closures cause the bear problems (Koon 1984). The issue is further intertwined with debate over the effects of supplemental feeding, baiting, human use of grizzly habitat, and other management actions (Boyd 1984; Hackett 1983; Koon 1984; Simpson 1985a).

Numerous agencies and individuals have been involved with grizzly management and research in the last decade. As they have developed grizzly policy and implemented it, the public and members of the political structure have all too often perceived lack of common purpose (Koon 1984; Melnykovych 1985) and have consequently questioned the competence and even motivation of key participants (Boyd 1984; Hackett 1983; Ogden Standard-Examiner 1984; Snodgrass 1984; Simpson 1985b). If the "experts" do not agree, the public may well ask, do they know what they are talking about?

Management Implications of Grizzly Population and Mortality

The population of Yellowstone GBE was estimated at 200 to 350 grizzlies when the recovery plan was written (USDI 1982). More recently, the Interagency Committee adopted a minimum population estimate of 183 to 207 bears. Regardless of the precise number, which is obviously difficult to establish, managers found themselves faced with an apparently low population and information suggesting a proportionately small breeding female bear population of 30 or fewer animals. Given the known rate of grizzly mortality, the small breeding population indicates a marginal ability of the Yellowstone population to sustain itself. On the heels of this disquieting information, 14 known human-caused bear mortalities and 3 natural mortalities occurred in 1982 (table 1). Logically, managers and researchers concluded that the immediate thrust of bear recovery should be to reduce human-caused mortality, with particular concern for breeding females (Mehrhoff 1982).

Table 1 depicts known mortality by generalized cause for the period 1980 through 1984, based on a composite of agency records and annual reports (Orme 1984). These 48 known bear deaths yield an average loss to the system of 9.6 bears each year, with 1982 showing the most known losses (17) and 1983 the fewest (6). No definitive trend over time is discernible from the data, but the information suggests certain activities that have contributed consistently to mortality and warrant management attention.

Surprising, perhaps, is the relative lack of mortality associated with resource use such as grazing or timber harvest (table 1). Large parts of the occupied habitat are within National Parks and National Forest wilderness, but a significant portion is within National Forest and other land ownership where timber

harvest, grazing, and other resource use takes place.

None of the mortality for this 5 year period is confirmed to be directly involved with such National Forest resource use or related activities, but the first year of the Bear 38 incident did involve National Forest grazing (Matejko and Franklin 1983). One other bear mortality indicated in table 1 is possibly linked to grazing activity and is under continuing investigation. In any case, known human-induced mortality or losses for the past 5 years are largely related to recreational activities such as camping or hunting, and the attractants associated with areas of human habitation such as West Yellowstone, Montana.

Efforts of managers, however, have not always been guided by the latest information or by hard-nosed interpretation of basic data limitations and reliability (Burns 1981b). Unfortunately, this has fueled the public perception of disagreement among managers, contributed to the alienation of important segments of the local economic and social structures, and resulted in political reaction limiting or altering the management latitude for recovery, as is discussed later.

Table 1.--Yellowstone GBE known mortality by cause for 1980 through 1984

Year	Known mortality or loss	Natural causes[1]	Unknown causes	Road (vehicle)	Hunter related[2]	Self defense[3]	Control export[4]	Handling accident[5]
1984	9	1	2	0	0	1	3	2
1983	6	(1)[6]	0	0	0	0	4	2
1982	17	3	1	0	5	1	5	2
1981	9[7]	2	1	1	4	1	0	0
1980	7	2	0	1	2	0	1	1
Total	48	8	4	2	11	3	13	7
Ave Year	9.6	1.6	0.8	0.4	2.2	0.6	2.6	1.4

[1] Usually malnutrition,

[2] Includes some apparent poaching incidents,

[3] All hunter-involved self-defense incidents,

[4] Includes bears which were killed for public safety as well as those turned over to zoos,

[5] All associated with research, export, or relocation efforts,

[6] Cub of control action-bear not expected to survive winter,

[7] In 1981 an additional six unverified mortalities were reported.

NOTE: A hunter related mortality for 1984 has since been verified, which increases the total known loss for 1984 to 10 bears, the average/year hunter related loss to 2.4.

TARGHEE NATIONAL FOREST

Use of Mortality Data in Section 7 Consultations

An examination of the pre-1980 mortality statistics for the Targhee National Forest (table 2) provides insight into why political controversy has ensued from their use. Initial estimates of sheep-related bear mortality were compiled from annual grazing reports and other sources (Jorgensen 1979). After adjustments to eliminate duplication, this estimate formed the basis for the 1960-79 mortality figures included in the biological evaluation submitted by the Targhee National Forest as part of the Section 7 consultation on grazing in grizzly habitat (Lee 1981).

The mortality data summaries tended to be widely accepted as a definitive portrayal of mortality associated with sheep allotments before 1980; in fact those who developed these summaries recognized serious difficulties with the raw information (Burns 1981b; Lee 1981; Jorgensen 1979). More significantly, managers and others often overlooked the fact that the grizzly was not classified as "threatened" until 1975, and the grazing-associated mortality before that date--of whatever magnitude--was legal (table 2). After listing of the grizzly on August 1, 1975, the situation altered drastically. Before 1975, not only did State law permit and tend to encourage the killing of livestock predators, but the very cultural fabric and economic necessity of the livestock industry provided strong incentives to do so. From a legal and administrative point of view, the acceptability of grizzly mortality completely reversed in 1975 as a result of listing. Conclusions about past mortality patterns could be drawn from judicious use of the data, but with the drastic change from a legally sanctioned act (when killing grizzly to protect stock) to a felonious act meant the information could not be used to project future mortality patterns (Burns 1984f).

The level of mortality shown for 1976 to 1979 in table 2 suggests that mortality continued or even increased on some sheep allotments following listing of the bear. When, however, we understand that only one of those seven (bear No. 14) was a known loss (Lee 1981), another aspect of the data is brought to light: how much weight should be placed on unverified reports as a basis for management (Burns 1982b)?

To place the mortality data in perspective and gauge its reliability and implications, the origin of the information must be understood. The historical record of losses developed from a variety of sources, but relied heavily on grazing reports filed annually with the U. S. Department of Agriculture, Forest Service, and other information provided by the grazing permittees. Estimates by different investigators for similar periods varied greatly and were difficult to reconcile (Griffel 1976a; Johnson 1976; Knight and Judd 1980). The grazing reports typically list losses of livestock to various causes such as predation, accident, or poisonous plants, as well as predators killed. For the most part a permittee relies on information provided by herders. The local ranger in turn relies on information submitted by the permittee.

In evaluating raw data reliability, one must keep in mind that aside from outright guesses by permittees and rangers, incentives existed for exaggeration or misstatement. A poor herder who loses 20 sheep by letting them pile up in a gully and suffocate may find it expedient to attribute the loss to a bear, rather than to inattention or error. In addition, narratives of bear incidents tend to be repeated and even enhanced, and such narratives repeatedly enter the reporting and investigating system as "incidents." As a result, unverified, "word-of-mouth" stories contribute to the incident reports and to mortality estimates. Such data have contributed to the tally of unverified losses, such as six of the seven from 1976 to 1979. As the aggregation or summarization process flows, the limitations placed on the initial data tend to be obscured (Burns 1982b).

Effect of Mortality Patterns on Bear Recovery Programs

The point, of course, is not to dispute the estimated number of kills developed from various sources but to point out that these estimates, once formulated, were taken by many at face value, which contributed to strong reaction against sheep use of grizzly habitat. Persons and organizations active in bear recovery relied heavily on the estimates to build public opinion and implied that the livestock owners would likely continue to shoot grizzlies near their flocks (Knight and Judd 1980; Griffel 1976b; McNamee 1984.) Using the 1960-79 mortality estimates to draw attention to the bear's

Table 2.--Grizzly bear mortality on sheep allotments, Targhee National Forest

Years	Two-Top/Reas allotments	Squirrel/Boone allotments	Other allotments
1960	2		
1965	1		
1966	1		
1967	1		
1968	1		
1969	2		
1970	5	2	
1971	1	2	
1972	2	1	1
1973	1	2	1
[1]1974-75	2	1	
1976-79		[2]7	
1980-84			[3]1

[1] Grizzly "listed" as threatened on August 1, 1975. Mortality for 1960 through 1975 legal under State laws.

[2] Bear 14 mortality only one of the seven "incidents" that could be verified.

[3] In 1984, a mortality of unknown cause was verified on a sheep allotment not in situation 1 habitat. It is under investigation.

plight was highly successful in one sense but also alienated the sheep ranchers, who felt they were being singled out as the scapegoat. To those attempting to build a broad-based consensus for bear recovery, continuous finger-pointing at the grazing industry was counterproductive (Burns 1982a).

Section 7 Consultation and No-Jeopardy Opinion

By 1980, Forest Service personnel and sheep permittees had arrived at an adjusted pattern of grazing in the Targhee's Situation 1 bear habitat, which was submitted for formal Section 7 Consultation in 1981 (Lee 1981). This pattern was intended to minimize bear-livestock conflict potential by providing room to maneuver for the grazing operations, as well as by avoiding certain areas of historic bear-sheep contact such as Winegar Hole. During this period, the economic situation in the sheep industry encouraged having smaller numbers on the range, a trend that no doubt made the adjusted pattern of reduced numbers and allotment consolidations easier to achieve. Table 3 shows the permit "obligation" (number of mature animals under permit and the number of allotments open) in situation 1 grizzly habitat in 1975, 1980, and 1984.

This adjustment, coupled with Targhee plans for intensive on-site monitoring of grazing activity and bear use in situation 1, received a U.S. Fish and Wildlife Service no-jeopardy opinion

(Mehrhoff 1981). A key element of the opinion was the aggressive monitoring program outlined by the Forest. Supplemental consultation on later adjustments in the grazing season received a similar no-jeopardy opinion (Mehrhoff 1982) indicating that the grazing program did not constitute a threat to the continued existence of the grizzly.

TREND OF POLITICAL INVOLVEMENT

Centennial Mountains Wilderness-Sheep-Grizzly Conflict

By coincidence, during this period of adjustment the BLM began a wilderness study of its existing BLM Centennial Mountains primitive area, located on the Montana side of the Centennial Range. The area is not within situation 1 habitat. The U.S. Sheep Experiment Station summer rangelands lay within the primitive area, and the wilderness study evolved into a sheep-grizzly controversy. The issue was settled when provisions in the appropriation legislation for BLM prohibited further use of funds for the wilderness study (Burns 1981a). Subsequently, the Sheep Station lands in question were transferred from BLM jurisdiction to the Department of Agriculture. Since then, the wilderness study has resumed but with mandatory exclusion from study of the rangelands used by the Sheep Station.

Message to Managers

To managers accustomed to the historical interactions of the political process with controversial or intense land management questions, the prohibitive legislation was not surprising. First through the appropriations process and then through direct action, Congress simply defined certain boundaries of politically unacceptable bear habitat. The larger message, however, was clear to those who chose to heed it: if managers do not make bear recovery and traditional land uses compatible, the legislative process will resolve the disputes. Other conflicts involving threatened or endangered species have followed a similar pattern when the social or economic structure was significantly affected. The snail darter-Tellico Dam controversy (Campbell 1983) is perhaps the most well known example. In the Rockies, the question of wolf reintroduction seems headed in the same direction (New York Times 1985).

Bear 38 Incidents

Unfortunately, compatibility between uses was elusive. In the late summer of 1983 the protracted incident of Bear 38 and her two offspring, Nos. 101 and 102, took place (Matejko and Franklin 1983). The bears killed sheep, first on the Two-Top allotment and later on private ranch lands. Because the private lands abutted

Table 3.--Number of allotments and permitted sheep numbers in situation 1 grizzly habitat, Targhee National Forest

Year	Number of open allotments [1]	Number of sheep [2]
1975	11	10,600
1980	6	6,200
1984	3	3,000

[1] Data for 1980 reflect consolidation of allotments and reduction in numbers as a result of Forest Service effort to reduce conflict potential in grizzly habitat, as well as effect of personal-convenience nonuse by permittees. Data for 1984 reflect additional effect of personal-convenience nonuse by permittees, plus temporary shift of Two-Top band of 1,100 head to allotments in Centennials to avoid repetition of Bear 38 interaction.

[2] Figures are mature animals. Normally, mature ewes under permit will be accompanied by one or two lambs.

the situation 1 boundary (also the Forest boundary), the focus of the incident became the agencies' collective ability--or willingness--to respond to "on-and-off" movements of the bears (that is, out of situation 1 onto private land and back) plus the need for more visible decision making during a bear incident. A well-attended public meeting included Congressional staff, local State legislators, county officials, numerous ranchers, and local residents. Considerable correspondence followed between legislators and administrators on incident authority and procedures for coping with problem bears when both private land and situation 1 were involved (McClure and Symms 1983; Siddoway 1983; Tixier 1984a,b). Again, a clear message was being sent to make political and biological habitats compatible.

Attempted Resolution

In an effort to defuse growing political concern, the Targhee Forest proposed supplemental language to the Yellowstone Guidelines which would identify a specific leader to handle such incidents as well as assure private landowners that constructive actions were being taken (Burns 1984c). Forest personnel cautioned that a failure to respond constructively could result in appropriations or legislative restrictions, as well as risk opening the Yellowstone Guidelines to review and possible modification. Considerable discussion of the proposals took place during 1983 and 1984, but managers did not agree to adopt the proposed changes (Buterbaugh 1985).

Later Management Actions

In 1984, in an effort to prevent a probable recurrence of bear-sheep conflict on Two-Top with Bears 38, 101, and 102, the sheep were shifted (over the objection of the permittee) to an alternate group of allotments outside situation 1 (Burns 1984a,b,d,e; Rigby 1984; Symms 1984). A conflict involving Bear 38 did take place but on private land outside the National Forest adjacent to the Two-Top allotment (Matejko and Franklin 1984). These events, plus concern for population augmentation elsewhere, resulted in the predicted appropriations restrictions, as well as requirements to publish the Yellowstone Guidelines in the Federal Register, hold public meetings to receive comment, and process the guidelines through the Federal rule-making procedure (Buterbaugh 1985). Additional legislative provisions were included to compensate permittees who incurred moving costs due to grizzly management actions (U.S. Laws 1985; Coston 1984).

THE POLITICAL FUTURE

Reality of Congressional Compromise

The message of Congress was clear in the 1985 Continuing Appropriations Act, but will it be heeded by managers? Unfortunately, the subtle functioning of our political process is often not fully appreciated by those deeply involved in controversial issues. Indeed, the temptation exists to perceive the outcome of issues in terms of how the votes might line up or where the majority of the United States population might stand if the specific issue somehow came to referendum. Too often overlooked is the fact that Congress is designed to produce compromise, and elected representatives must constantly balance national perspective against constituent desires (Kennedy 1964). The Senate, in particular, traditionally functions to respect the wishes of the State delegation, particularly if members occupy important committee or party positions. Consequently, the U.S. Senators involved in the grizzly issue in the Yellowstone area exercise a much greater level of influence and control than might be expected from a cursory assessment of the "national balance of power" on threatened and endangered species questions.

A temptation also exists to discount the trend of the political concern. An Audubon representative, speaking recently at the Idaho Woolgrowers Convention, cautioned the livestock interests that in a direct confrontation between their industry and the bear, they would lose (Idaho Wool Growers Bulletin 1984). Although this is possibly true, another view suggests that the political structure is responding to a much wider range of constituents' concerns about bears--not just the grazing-grizzly questions.

The Breadth of Public and Political Concern

The range of concern and interactions of external publics can be illustrated by a few examples: Future use of the unique grizzly habitat at Fishing Bridge in Yellowstone National Park is the subject of intense social, economic, and political interest. The issue of relocating visitor facilities is being debated not just on what is best for the bears but best for the economies of Teton and Park Counties, WY, the city of Cody, park concessionaires, and others (U.S. Department of the Interior 1985). Elsewhere, Ron Marcoux speaking for the State of Montana and the International Association of Fish and Wildlife Agencies (1985) before a Congressional subcommittee observed "we are left without substantive influence in actions originating from this Act (T&E Act), while bearing their consequences." Montana and the Association urge a "partnership" in managing the bear. A Wyoming biologist publicly expresses concern that bear experts are "losing their credibility," as well as control of the situation and public respect (Melnykovych 1985) and suggests limited hunting. An outfitter in grizzly country insists "the interests of the people who use the National Forests are being ignored" (Snodgrass 1984). His statements that unnecessary regulations and closures will adversely affect the sportsman, livestockman, lumberman, and so on are not falling on deaf or unsympathetic ears. Similar voices are making themselves heard throughout grizzly country (Buterbaugh 1985), and the political process is reflecting them (Simpson 1985a,b).

The crucial factor is not whether support for grizzly recovery can overcome conflicting individual interests such as livestock, timber, black bear hunters, recreationists, and tourist services, but whether these disparate interests--each of which rightly or wrongly perceives a threat in the current course of grizzly management --will coalesce and prompt further political delineation of grizzly habitat and management practices. The result may or may not conform to biological habitat and, if history is a guide, the two will not perfectly match.

PROSPECTS FOR MERGING BIOLOGICAL AND POLITICAL HABITAT

Effect of Restrictions

Managers still have time to refine and channel a grizzly recovery effort that incorporates all facets of the social and political structure. Many positive efforts are taking place, but managers must remember that each additional restriction imposed in grizzly habitat by definition must adversely affect someone, some action, or some interest. The list of bear opponents tends to widen regardless of how desirable any given restriction is to recovery. Each year sees additional actions such as eliminating black bear baiting, moving grazing permittees, food storage requirements, seasonal use limitations, and so on. Constraints are obviously necessary, and some historic uses must continue to evolve and change, but the modifications need to be made in a way that builds friends for the bear, not enemies.

Expression of Social Needs

Social needs and their expression through the political process typically differ from locality to locality. Even the most casual observer will note that the residents of Jackson Hole, WY, have somewhat different perspectives on natural resources utilization and management than do the residents of Teton or Fremont Counties, ID. Similar levels of differing perspective occur elsewhere, but managers must increasingly focus on finding a socially acceptable common denominator for bear management actions. The concept of grizzly recovery still enjoys virtually universal acceptance, but it is folly to take broad-based public support for granted or to ignore the social complexities of the public living with or close to the grizzly (Montana Department of Fish, Wildlife and Parks 1985).

Since its inception, the Forest Service has recognized that local support by National Forest users is vital to success of any management effort. And where local or regional support has been lost, or could not be obtained, national programs have ultimately changed. No better example exists than the history of the establishment of the National Forests themselves: broad authority was given by Congress to the Executive Branch to create forest reserves from the public domain, that authority was later removed

for most of the Western States, and the National Forests were subsequently opened to homesteading as a "safety valve" to prevent loss of the system altogether (Pinchot 1972). Overall, the management practices for the various activities on the National Forests, such as grazing, result far more from social evolution and consensus building than Federal rule-making (Roberts 1963).

Complexities of Recovery Consensus

The critical components of a consensus or broad support for a grizzly management strategy probably differ in each GBE. No study, or indeed comprehensive effort, has yet been undertaken to identify bear-related social and political issues on an ecosystem basis. Lacking that, the absence of a framework to integrate grizzly recovery with other public issues or concerns is not surprising. Local managers do attempt to meld the recovery effort with the social and political climate in their zones of influence, but this is not always fully effective, lacking as it does the flexibility or latitude for compromise needed to obtain broad-based support for natural resource decisions (Pinchot 1972). As a result, local efforts at compromise are often typecast as being "antibear" or "antiuse," depending upon the viewer's perspective and the nature of the issues involved (Simpson 1985a,b; Ruemenapp 1985.)

CONCLUSION

In the end, as with all public undertakings, the grizzly will not be saved by just those with noble purpose or determined commitment to the cause (Kennedy 1964; Symms 1985). Idealism, laws, fines, restrictions, or changes in land use won't do it either, but some will be needed. Nor will members of Congress, forest rangers, game wardens, committees, or bureaucrats pull it off, although they too will help. Recovery will be accomplished by ordinary people who live and work in and near grizzly country and who are comfortable with where the line is drawn between bear priorities and human priorities (Montana Department of Fish, Wildlife and Parks 1985). When that comfort level is reached, the political habitat will correspond to the biological.

Senator Steve Symms (1985) of Idaho recently summarized the recovery challenge facing managers. He said:

> The protection of endangered species cannot be carried to a point where it conflicts with the demands of society. We must remember that our national goal to protect these species was established at the request of society, and was not a self-perpetuating objective born in the bowels of a government bureaucracy. Habitat management policies that ignore the needs of individual members of society are therefore counterproductive, and in the end, may only serve to weaken the public's desire to fulfill this important stewardship.

Due to the intense interest, inspired research, and commitment of many individuals and organizations, managers now have better information and more refined techniques at their disposal. This, coupled with a wealth of public interest and concern can ensure the recovery of grizzly if used intelligently and with discretion. Some have suggested that recovery of the grizzly is an ethical "test" of society. That is not wholly true. A bigger challenge is for managers and researchers to use our scientific, social and political resources to build strong local consensus for bear management in all parts of every grizzly bear ecosystem. To do that, we will have to ensure that every National Forest and National Park user, each rancher and landowner, and the involved Senators, Congresspersons or Representatives, State legislators, county commissioners, concessionaires, and chambers of commerce agree that the course of action is both sensible and fair.



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HABITAT RESEARCH NEEDS FOR GRIZZLY BEAR RECOVERY

Christopher Servheen

ABSTRACT: Past grizzly bear habitat research in the contiguous 48 States includes a significant amount of information on the general biology and habitat needs of the species in the Yellowstone and northern Continental Divide ecosystems. Continued work on general biology and habitat needs is continuing in the Cabinet/Yaak and Selkirk ecosystems, and work is planned in the Selway/Bitterroot and North Cascades ecosystems. Research emphasis has now shifted from site-specific, general biology studies to topical studies directed at the effects of human-related activities on grizzly bear behavior and habitat use. Future research is needed on the concept of carrying capacity, habitat effectiveness, the predictability of annual and long-term food variation within and between ecosystems, the independence of ecosystems from environmental randomness, the effects of human activity on movement patterns to prevent habitat fragmentation, and the development of a predictive habitat use model.

INTRODUCTION

The survival of the grizzly bear depends upon many factors: habitat preservation and management, minimizing excessive human-induced mortality, and citizens' understanding about what is necessary to preserve the species. Habitat management depends upon specific information about what the grizzly bear requires to survive and the effects of human activities on the availability and use of these necessities.

Intensive habitat research on the grizzly bear began in the lower 48 States with the work of Frank and John Craighead in the Yellowstone area between 1959 and 1970. When the grizzly was declared a threatened species in 1975, research on grizzly bear biology and habitat needs expanded through almost all areas of remaining habitat in the lower 48 States. Most efforts on habitat research since 1975 have focused on basic habitat use parameters and food habits of the species in the varied habitats in the lower 48 States.

Habitat use and preference information and food habits by season have been analyzed in the Yellowstone Ecosystem using habitat type base maps and more than 3,900 locations gathered using radio-collared bears since 1975 (Knight and others 1984). This analysis has produced a clear picture of grizzly bear food habits and habitat use patterns in this ecosystem.

In the northern Continental Divide grizzly bear ecosystem, habitat preference information has been determined in several study areas (Servheen and Lee 1979; Mace and Jonkel 1980b; Schallenberger and Jonkel 1979, 1980; Zager 1980; Aune and Stivers 1981, 1982, 1983; Servheen 1983; McLellan and Mace 1985) by comparing habitat use from radio locations to habitat availability within the home range of radio-collared animals (Marcum and Loftsgaarden 1980). Several of these studies on the basic habitat requirements of the grizzly in different areas of this ecosystem are continuing.

Grizzly bear habitat in the Cabinet/Yaak ecosystem has been intensively mapped as part of a habitat management program by the Kootenai National Forest (Christensen and Madel 1982). Using this habitat mapping as a foundation, the ongoing grizzly studies in the Cabinet/Yaak ecosystem (Kasworm 1984, 1985) are continuing to gather basic information of the habitat use patterns and distribution of this small population.

The Selkirk ecosystem in Idaho and Washington has been surveyed for grizzly habitat suitability (Zager 1983), and the area is being mapped as part of the habitat management program by the Idaho Panhandle National Forests. Basic information on habitat use and distribution in this area was gathered as part of a master's study at the University of Idaho by Jon Almack (1985) and further work is planned along the Canada-United States border in 1986.

Habitat in the North Cascades ecosystem has not been mapped or surveyed, although Sullivan (1984) completed a survey on the historical distribution of the grizzly and the validity of recent sightings in this area. A portion of the Selway-Bitterroot ecosystem has been surveyed for grizzly bear habitat suitability (Scaggs 1979) and further work that delineates important habitats and determines the suitability of present habitats to support bears will begin in 1985.

Thus, considerable information on the basic biology and habitat needs of the grizzly has been gathered since 1975 in four of the six ecosystems where the grizzly remains. Ten years of research have produced considerable baseline information in the Yellowstone and northern Continental Divide ecosystems on habitat use patterns, food habits, and movements. Less information is available in the remaining four ecosystems, and work on basic grizzly bear biology will continue in these areas.

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Information on basic biology and habitat needs has been developed through site-specific studies on the biology of the grizzly population in the area of interest. Using site-specific data, land management agencies have been able to develop management guidelines for important seasonal habitats. Such guidelines have been the basis for managing road and trail closures in important seasonal range; limiting disturbances in denning areas; establishing helicopter flight lines and seismic exploration guidelines to avoid important seasonal use areas; and timber harvest stipulations in grizzly habitat.

CURRENT EFFORTS

Since the approval of the Grizzly Bear Recovery Plan in 1981 and the implementation of the Interagency Grizzly Bear Committee research planning effort starting in 1983, the direction of research on the grizzly bear in the lower 48 States has shifted. This was due in part to the recognition that available information on the general biology and habitat use of the grizzly in the Yellowstone and northern Continental Divide ecosystems was adequate to make general management decisions for the species in these areas. It was also recognized that baseline information was still necessary from the other four ecosystems.

The shift of research direction since 1983 has been away from the site-specific, general bear biology studies of the past to topical studies focusing on the effects of certain human activities on the behavior and habitat use of the grizzly bear. These topical studies are designed to supply information on how bears relate to specific activities so these can be more effectively managed. This information is necessary as management becomes ever more fine-tuned and managers are called upon to specify why certain management actions are necessary and whether these actions improve conditions for the species. This specific information on the effects of certain human activities is necessary if the public is to be convinced that management decisions are legitimate and necessary. In addition, the cumulative effects analysis process requires specific information on the influence zones of certain human activities such as recreational trail use, roads, backcountry camps, and helicopter overflights so these zones can be incorporated into the new computer-based cumulative effects analysis process.

Increasing natural resource and recreation demands in occupied grizzly bear habitat create disturbances which can take two forms:

1. Ecological disturbance changes the structure of the physical landscape and results from such activities as timber harvest, fire, petroleum development, housing subdivisions, developed campgrounds, or livestock grazing. Ecological disturbance affects the presence of resources and can be permanent or at least long-lasting. Whether an ecological disturbance is a positive or negative factor in grizzly bear habitat depends on its application.

2. Behavioral disturbance and loss of solitude results from such activities as helicopter use, recreation, petroleum exploration, or road use. Behavioral disturbance changes the use and availability of existing resources without changing their character and is usually temporary.

Examples of ecological disturbance studies in the lower 48 States include Zager (1980) on the effects of wildfire and timber harvest and Aune and Stivers (1981, 1982, 1983) on livestock grazing and oil and gas development. Examples of behavioral disturbance studies include Mace and Jonkel (1980a) on timber harvest, McLellan and Mace (1985) on the effects of roads and helicopters, and Schleyer and others (1984) on the effects of backcountry recreation. The majority of research on ecological and behavioral disturbance in the lower 48 States focuses on oil and gas exploration and development, backcountry recreation, and roads and motorized road use.

If the effect of habitat disturbance is most profound in pristine areas, documentation of this fact is important to management of much of the remaining grizzly bear habitat in the lower 48 States. The increased demand for oil and gas exploration and development is a prime example of a human disturbance that will soon be introduced into most of occupied grizzly habitat outside national parks and some wilderness areas (Schallenberger 1980). Ecological and behavioral disturbance will continue to increase in grizzly habitat. Because much occupied grizzly range is multiple-use land, exclusion of human activity is not possible or desirable. Successfully minimizing the negative effects of human disturbance will depend upon management decisions based on sound information about the effects of both ecological and behavioral disturbance.

FUTURE NEEDS

Certain questions concerning habitat remain to be addressed for the successful recovery and future management of the grizzly bear in the lower 48 States. In general, these questions involve ecological principles and the application of the concepts of conservation biology to the management of the species.

We must apply the concept of carrying capacity to the grizzly bear if recovery targets are to be realistic and achievable, but because the grizzly bear is an opportunistic omnivore that uses diverse foods that vary annually, it is difficult to apply this concept. It may be necessary to determine carrying capacity through long-term observation of annual food resource changes and the subsequent responses of bear populations. There has been little thought given to this concept for the grizzly to date, and its solution may require careful integration of ecological, environmental, and social factors for the species.

Although there is considerable speculation about the usefulness of the carrying capacity idea (Caughley 1979), the need to know how many bears

can exist on a given piece of occupied habitat is critical to the management strategies necessary for the survival of the species. This is especially important because grizzly territory will be limited to the areas occupied when the bear was declared threatened in 1975.

The concept of minimum viable population size (MVP) for the grizzly bear was pioneered by Mark Shaffer (1983). This concept underlies the minimum recovery targets of the Grizzly Bear Recovery Plan (U.S. Department of the Interior 1982). Applications of this concept to the grizzly bear are based on the genetic and demographic considerations of population size. Once the demographic and genetic considerations are met, a population level can be projected which has a certain probability of survival over a certain time period. This population level can then be the target of recovery management. The application of the concept is limited, however, by the habitat available for grizzly population recovery and the carrying capacity of that habitat. To legitimately apply recovery targets, the minimum viable population size must be applied to the available habitat and the carrying capacity of that habitat must be assessed to determine if the habitat can support the minimum population size. Thus, to properly apply MVP, we must have an estimate of the carrying capacity for each ecosystem.

The concept of carrying capacity is closely related to the idea of habitat effectiveness. In the past, habitat effectiveness has been considered the availability of the habitat to the bears in the area or the areas free from human influence. Habitat effectiveness ratings have been based on the relationship between available undisturbed habitat and the seasonal habitat requirements of the species. A uniform definition and application of this term is needed, especially as the cumulative effects analysis process is applied to all occupied grizzly bear habitat.

There is a need for uniform and standardized data collection on all habitat research within and between ecosystems. With different research projects in different areas, different habitat definitions frequently develop. These different definitions complicate the comparison of data between areas and frustrate management efforts to develop standardized management systems based on this habitat information.

The grizzly bear depends upon diverse food resources whose distribution and availability are often random. Examples are shrub fruits such as Vaccinium spp., whitebark pine (Pinus albicaulis) seeds, and carrion. An overall review and compilation of the annual changes in these foods' distribution and availability in each ecosystem is needed to assess carrying capacity and to predict the bear-human conflicts resulting from these variations.

The relationship of major food supply variations within and between ecosystems is not known, yet the independence of ecosystems with regard to these random events is important to successful management. To what extent variations are predictable according to weather or long-term cycles is a useful question for managers who must consider changes in bear food abundance and their effect on bear-human conflicts. If these patterns of food change were more predictable, bear and people management could attempt to mitigate their effects.

The relationship between habitat values and population limits has never been adequately described but it seems reasonable to relate changes in habitat productivity to demographic parameters such as ability to survive, reproductive interval implantation of blastocysts after females enter the den, and behavioral changes such as dispersal of subadults and changes in home range size. Determining the relationship between these demographic and behavioral parameters and specific habitat characteristics would make it easier to determine habitat-related limiting factors. This in turn would promote mitigation of the effects of these limitations and recognition of the facto influencing the rate of population recovery. Although we can now change certain grizzly bear habitat factors through timber harvest, prescribe fire, and planting certain food plants, there is insufficient information to demonstrate that these habitat components are the factors that limit populations.

The idea of habitat reserves has recently been suggested in British Columbia (Archibald 1983). These areas would provide refuge from most human-related causes of mortality. These reserves are projected to be high-production areas where populations reproduce at high rates. Subadult grizzlies from these areas could then populate the areas surrounding the reserves. Implementing this idea requires determining the habitat values and mix necessary to provide maximum production. In the lower 48 States, two possible reserves already exist--Glacier and Yellowstone National Parks. Further examination of the idea of habitat suitability and limiting factors will aid in the assessment of the reserve idea.

Preventing habitat fragmentation is also an important issue. Such fragmentation was a major factor in the elimination of the grizzly bear throughout much of the American West. It occurred when lands in occupied habitat were made unsuitabl through habitat alteration or where the grizzly was not tolerated. This fragmentation isolated small insular populations which then became more susceptible to random habitat factors and to killing by humans. As the human use of grizzly bear habitat continues, suitable movement corridors within existing habitat must be maintained. The remaining ecosystems are fragments of the former range of the species; further fragmentation will seriously threaten the potential for the recovery and survival of the species.

Maintaining entire ecosystems requires continuing the current integration of grizzly populations that span the United States-Canada border. At least four of the six remaining ecosystems in the contiguous United States share habitat and grizzly bear populations with Canada. The northern Continental Divide ecosystem shares the

largest border with Canada, and this connection may be the most imperiled. There is considerable timber harvest, road building, and oil and gas exploration and development on both sides of the border, and a major open-pit coal mine immediately north of the border is planned. We need to know the tolerance of bears for such human activities, the inhibitions to movement posed by such activities, and the changes in survival rates of bears that live in or move through such activity areas. The cumulative effects analysis process will allow us to realize the compounding factors that may exist along potential fragmentation lines where many activities threaten movement. To adequately manage these activities, we need to know what levels of development and activity influence movement patterns and how human activity influences dispersal patterns of subadults. These questions must be answered if we are to prevent further fragmentation of the remaining habitat.

Several grizzly bear habitat mapping methods have been developed with various levels of resolution (Servheen and Lee 1979; Zager 1980; Christensen and Madel 1982; Craighead and others 1982). This information will be used in land management planning and in implementing the cumulative effects analysis process. These methods need to be evaluated as elements of a conceptual model to predict grizzly bear habitat selection as proposed by Lyon (1985). If a mapping system can be used to predict grizzly bear habitat use, it could be standardized and applied to all occupied habitat.

Preliminary plans have been made to test existing mapping methods as part of a predictive habitat use model.

Continued progress in habitat research will depend upon coordination and cooperation between all agencies and support of those projects which are carefully designed to produce information needed to meet the management needs for recovery of the grizzly bear. Continued interagency coordination through the Interagency Grizzly Bear Committee will assure support for those projects that have been productive and successful.

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GRIZZLY BEAR HABITAT RESEARCH IN GLACIER NATIONAL PARK, MONTANA

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ABSTRACT: Grizzly bear habitat research began in 1967 and is continuing in Glacier National Park, MT. Direct observations and fecal analysis revealed a relatively definable pattern of habitat use by the bears. Habitat data were subsequently used to develop management models and explore the relationship between grizzlies and park visitors. Current research strategy is based on the concept that humans are an integral component of grizzly bear habitat. A geographic information system is being developed to assist in the application of habitat data. In addition, the behavioral response of grizzlies to annual changes in food production is being studied. Management that addresses bears, humans, and their habitat as a system is proposed.

INTRODUCTION

Grizzly bears (Ursus arctos) and paleolithic humans (Homo sapiens) are relatively recent additions to the megafauna of North America. Both species emigrated eastward from Eurasia and colonized Beringia during the Wisconsin glacial period. Humans dispersed toward southern continental areas early in the glacial period, and grizzlies followed after the continental ice sheet melted some 12,000 years ago. Except for that period between emigrations, grizzlies and humans have coexisted for millenia in holarctic habitats.

The advent of modern humans and their sophisticated weapons was significant to grizzly bear evolution. In Europe, exploitive pressures began nearly a thousand years ago and reduced bear population numbers and distribution substantially (Cowan 1972). Similar impacts occurred more recently in North America and were measurably more dramatic. The species currently occupies less than half of its historic range, and its status is tenuous south of Canada. On both continents, grizzly demographic responses have been accompanied by increasing shyness, a behavioral trait with distinct survival value.

Large national parks provided the first sanctuaries for grizzlies on the southern edge of their shrinking range in North America. Parks initially protected remnant populations that persisted in spite of intense exploitation. Subsequently park management goals included restoring grizzly bear numbers to those that existed under pristine conditions. This effort was unique in the historic relationship between grizzlies and humans in that it largely eliminated the demographic and behavioral consequences of bear mortality from hunting and other human-related causes. Most likely, this policy is at least partly responsible for the dynamic history of grizzlies and humans in the parks.

The relationship between grizzly bears and modern humans is reflected in the history of Glacier National Park, MT (Martinka 1976a). The bear population appears to have been heavily exploited, and numbers were low when the Park was established in 1910. Recovery took at least 50 years; only in recent decades have natural limits to population growth been approached (Keating 1983). Human use of the Park gradually increased over the same period and reached two million visits in 1983. Conflicts between the two species also increased, and there is now evidence that the incidence of human injuries and deaths is accelerating (Martinka 1982).

In 1967, grizzlies killed two campers in separate backcountry campsites in Glacier National Park. Their deaths prompted a critical evaluation of the relationship between grizzly bears and Park visitors. Not surprisingly, it was quickly discovered that little was known about either species and how they fit into the ecological matrix of the Park. However, it was generally agreed that both had a legitimate place and that conflict detracted from the potential for successful Park management. These conclusions inspired a scientific research program designed to gather information and explore means for separating the species and reducing conflicts. A first step toward that goal was to study the habitat in which conflict occurred, and thus grizzly habitat formed an important element of initial study design. This paper presents a synopsis of grizzly bear habitat research findings, describes current habitat research efforts, and attempts a conceptual synthesis of potential management applications in Glacier National Park.

COMPLETED HABITAT STUDIES

Originally grizzly bear habitat studies were descriptive and used traditional field observational techniques. Bear sightings were recorded and fecal samples collected during extensive coverage of the Park trail system. Although individual observers made few sightings, sample size was enhanced through a data base compiled from verified sightings from all sources. Sampling bias resulted from unquantified observer effort, variable reporting rates, observer confinement to roads and trails, and poor bear observability due to rugged topography and forest cover. However, habitat relationships were generally consistent with those

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determined using more sophisticated field technology such as radio telemetry.

Results of the early Park studies suggested that grizzlies were well adapted to postglacial mountain habitats (Martinka 1972, 1976a). Each of the major Park plant communities was used by the bears at some time during the season of activity from May through October. Although the bears frequented coniferous forests, they apparently preferred treeless habitats. Grasslands and alpine tundra provided open habitats; wildfire and snowslides created shrublands within the extensive coniferous forest zone. The distribution of grizzlies shifted in response to favored foods which included succulent herbs and nutritious fruits. Bears were most consistently associated with habitat diversity and abundant moisture.

Extensive field investigations identified two seasonal bear concentrations that were subsequently intensively evaluated. In 1969-70, Shaffer (1971) studied a late summer gathering on the Apgar Mountains. Results supported earlier observations that ripening huckleberries (Vaccinium spp.) were an important attraction to grizzly and black bears (Ursus americanus). Findings also suggested that niche separation occurred between the two species. From 1972 to 1975, Singer (1978) studied a spring concentration of grizzlies along the North Fork Flathead River. Wet meadows and alluvial seres were important habitats that provided rhizomatous grasses, succulent forbs, roots, and tubers. The timing of melting snow appeared to influence the intensity of the spring gathering in that greater numbers were present when snowmelt was late. Both studies demonstrated that seasonal coalescence was an important element of grizzly bear habitat relationships in the Park.

A series of grizzly bear incidents from 1974 to 1976 prompted an assessment of the field research program. It was apparent that knowledge about habitat relationships was improving but questions about the data's usefulness remained unanswered. To answer them, a series of four studies from 1975 to 1980 examined how people were distributed in grizzly bear habitat. Each study related human activities to existing habitat information.

From 1974 to 1977, studies focused on the backcountry travel patterns of visitors using the northern half of the Park (Stuart 1977a, 1977b, 1978). Stuart developed bear contact indexes from sighting data, trail characteristics, and habitat distribution and then constructed models to demonstrate the various management options available for altering the rate of contacts between grizzlies and visitors. The study accurately predicted that increasing backcountry use would lead to an even greater increase in the contact rate (Martinka 1982). In addition, a shift in management to prevent dangerous contacts (females with young) was proposed.

The wilderness travel project was accompanied by a backcountry campsite evaluation in 1975 (Merrill 1978). Ecological and sociological factors associated with damaged property and human injuries were compiled for 50 black and grizzly bear incidents. An unexpectedly high number occurred in deteriorated campsites in mature forests that were near developments and that had large party limits and good fishing nearby. Once again, niche differences were apparent in that a greater proportion of grizzly incidents occurred in the alpine zone and open canopy forests. Extensive changes have been made in campsite location since the study was completed.

In 1977, the research emphasis returned to grizzlies; one project explored food production as a means for predicting habitat use (Riggs and Armour 1981). Field effort focused on riparian habitats, involved intensive vegetation sampling, and used radio-tagged bear to measure habitat preference. Because selection patterns were consistent, the investigators believed that contact with the bear was avoidable. Unfortunately, the sample size of one radio-tagged bear precluded formulation of conclusions. In spite of this, it seemed reasonable to propose that changing the habitat use patterns of Park visitors could decrease the frequency of dangerous encounters.

Increasing confrontation rates provided incentive for a more detailed assessment of grizzly bear behavior toward people in 1980-81 (Jope 1982, 1985). The study examined habituation and its relationship to conflicts with humans. Results pointed to the importance of habituation as a process that allowed bears to exploit habitats being used by Park visitors. In addition, ancillary data revealed year-to-year changes in bear distribution that likely reflected geographic flux in habitat productivity. These conclusions emphasized the dynamic nature of grizzly bear habitat relationships as well as the potential for change with expanding human use.

CURRENT HABITAT STUDIES

Recent research has focused on habitat relationships as a key to understanding bear behavior and its influence on conflicts between bears and humans. The unique nature of bears ties them closely to habitat configuration and productivity. An inefficient digestive tract generalized for omnivorous habits combined with the demands of hibernation require that bears consume large amounts of food during their six months of activity each year. Because bears devote much of their energy budget to foraging, their distribution and activities should reflect environmental variation as it affects vegetation communities and other food supplies. Learning more about how bears adapt to fluctuations in their food resource may help predict behavior changes useful to management of bears and people.

This research direction was given impetus by another year of unusually severe conflict between grizzlies and humans in Glacier National Park. In 1980, three campers were killed in two separate grizzly bear attacks. We hypothesized that low huckleberry production in 1979 and 1980 and associated nutritional stress on bears triggered behavioral changes which increased the chance of dangerous encounters with people. This was compatible with previous studies which found that

forage productivity influenced grizzly bear habitat use (Riggs and Armour 1981; Jope 1982). Rogers (1976) and Picton (1978), among others, demonstrated the importance of climate and its effect on food availability to bear population parameters.

We began to test this hypothesis in 1982. The objectives were to expand understanding of seasonal food habits of bears throughout the Park, document annual fluctuations in the productivity of preferred bear foods, and examine the relationship between food availability and bear behavior (Kendall 1985b). Efforts thus far have been directed toward obtaining data on the first two objectives. Initial results have confirmed early food habits findings (Martinka 1972) and revealed dramatic fluctuations in productivity of huckleberries, a key bear food.

Results from the current food habits study corresponded closely with those reported for the 1967-71 period (Martinka 1972; Kendall 1985b). When these two data bases were combined they provided a representative picture of Park-wide bear food habits (table 1). Several generalities were evident from preliminary analyses. The dominant bear foods were grasses and sedges, umbels (notably Heracleum lanatum and Angelica spp.), and huckleberries. Animal protein, roots, and bulbs apparently played only a minor role in bear nutrition in Glacier National Park. Although use of grasses, sedges, and succulent forbs remained fairly constant each year, consumption of huckleberries and other fruits varied. These patterns reflected food availability and subsequent habitat use. In a typical year, huckleberries from high-elevation shrubfields were the principal food of late summer and fall. When huckleberry crops were poor, bears increasingly moved to low-elevation riparian areas to feed on hawthorn (Crataegus douglasi) berries and other foods.

Huckleberries became the primary focus of food availability studies because production appeared to vary more than in other important bear foods. Work conducted since 1982 has documented large year-to-year changes in huckleberries available to bears (Kendall 1985b). In 1983 and 1984, berry production was approximately 35 percent of the previous year; this was an 88 percent decline in huckleberry crops in a three-year period. This work also produced convincing evidence that huckleberry production could be regionally synchronous. The decreases in production were nearly ubiquitous throughout the Park, with declines in over 90 percent of the sites studied in both of the past two years. The next step should be to determine if berry production levels change bear-foraging activity and contribute to bear-human interactions.

Another variable, berry phenology, was also found to influence bear distribution. Aerial surveys designed to monitor grizzly bear population trends have taken advantage of bear concentrations in the shrubfields of the Apgar Mountains (Kendall 1983, 1984, 1985). Bears move into this area as huckleberries mature (Shaffer 1971). Variation in ripening dates and in numbers of bears sighted suggests that knowledge of the ripening process is an effective tool for predicting when bears congregate each year (Kendall 1985a). Linking flight schedules with berry phenology was considered essential for biologically significant year-to-year consistency in surveys designed to track long-term population trends.

Considering both bears and people as elements of the park ecosystem set the stage for further research. In a recent effort to describe the relationship between grizzly bear and human use of the Park (Baldwin and others 1985), researchers mapped grizzly habitat and backcountry visitor use in a portion of the Park. By overlaying these two data bases, the potential for conflict could be evaluated.

Grizzly habitat was mapped in the Two Medicine area of the Park using Glacier's Geographic Information System (GIS) (Butterfield and Key, this proceedings). The GIS classified vegetation by combining Landsat spectral data with digital terrain information. Vegetation classes were grouped into units representing vegetation associations exploited seasonally by grizzly bears. The groupings were based on habitat and food habits information for Glacier National Park (Martinka 1976a; Kendall 1985b) and extrapolation from other studies. Ground verification indicated that the technique provided detailed information on forested areas and habitat mosaics but did not effectively distinguish among moist, shrub-dominated sites. It was felt that the incorporation of ancillary data, such as burn perimeters, snowslide reaches, and riparian corridors would solve this problem allowing the system to provide general but accurate grizzly bear habitat information.

Visitor use patterns of the same area were mapped using a trailhead survey, which provided information on backcountry visitor activities and their use of the Park in space and time (Baldwin and others in preparation). The visitor mapping technique was an effective tool that could be adapted to a variety of situations and information needs. Integration of grizzly habitat and human use patterns revealed high numbers of hikers concentrated in the highest quality bear habitat. However, potential conflicts were minimized because most human use occurred during periods when bear use was not likely. It was concluded that knowledge of grizzly bear habitat needs has limited usefulness to Park managers without understanding the role of humans in that system.

CONCLUSIONS

Habitat studies have been an important part of the grizzly bear research program in Glacier National Park, and the knowledge contributed by them has improved our understanding of the ecological niche of grizzlies in the park environment. Study results also pointed to the likelihood that humans occupied an overlapping niche and competed with the bears for available habitat. It therefore seems appropriate that bears, humans, and their habitat be managed as a system. Field application of this concept requires that habitat be treated as a resource shared by the two dependent species and that management decisions be based on credible habitat information.

Table 1.--Seasonal food habits of bears in Glacier National Park, MT, from analysis of 943 scats sampled 1967-71 and 1982-84

Food Item		Percent frequency and volume[1] Apr.-June (N = 294)		July-Aug. (N = 304)		Sept.-Oct. (N = 345)	
Grass, sedge, rush							
	Total	55	40	45	17	40	21
Herbaceous material							
Angelica spp.		2	1	8	6	1	1
Heracleum lanatum		20	16	17	14	4	3
Misc.[2] umbels		27	16	23	16	4	1
Misc. forbs		20	7	19	6	14	8
Equisetum spp.		24	9	11	4	2	1
Misc. other[3]		5	[4]T	7	T	5	T
	Total	71	49	63	46	26	13
Fruits							
Amelanchier alnifolia		0	0	6	3	10	5
Crataegus douglasii		0	0	2	1	14	13
Sorbus spp.		0	0	0	0	9	5
Vaccinium spp.		0	0	29	19	38	24
Misc. fruits		5	1	6	2	10	4
	Total	5	1	44	26	81	51
Animal							
Insects		21	1	28	4	4	1
Mammals		21	7	7	2	11	4
Fish		0	0	0	0	1	T
	Total	37	8	32	6	13	6
Roots, bulbs							
Erythronium grandiflorum		1	T	8	3	0	0
Hedysarum spp.		3	2	2	1	8	7
Misc. roots		1	T	1	T	3	2
	Total	4	3	10	4	11	9

1/ Total volume for each season may not equal 100 percent due to rounding error.

2/ Items comprising less than 5 percent volume during one season were grouped under the miscellaneous category.

3/ Shrubs, trees, and miscellaneous nonflowering plants.

4/ Less than 0.5 percent of scat volume.

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USING GRIZZLY BEAR HABITAT INFORMATION TO REDUCE HUMAN-GRIZZLY BEAR CONFLICTS IN KOKANEE GLACIER AND VALHALLA PROVINCIAL PARKS, BC

Wayne McCrory, Stephen Herrero, and Phil Whitfield

ABSTRACT: Valhalla Provincial Park and Kokanee Glacier Provincial Park, located in rugged southeastern British Columbia, support grizzly bear (Ursus arctos) populations and increasing human use. To better manage future conflicts between park visitors and grizzlies, information was gathered on grizzly bear habitat capability and utilization employing the transect method. This information was integrated into master planning (zoning), and the planning and management of trails, campsites, and mountain huts. Various examples and comparisons are given for both parks. The advantages and limitations of the transect method are discussed.

INTRODUCTION

The Province of British Columbia is larger than California, Oregon, and Washington combined. Most of British Columbia is sparsely populated and is still inhabited by grizzly bears, whose population has been estimated at 6,000 to 8,000 (Pearson 1977). About 4.5 percent of the land base is in provincial parks, many of which are in remote grizzly bear country that receives limited recreational use. Use of the wilderness is rapidly increasing, however, in some British Columbia parks, bringing more people in contact with grizzly bears. To reduce conflicts between people and grizzly bears, the British Columbia Ministry of Lands, Parks and Housing instituted a limited study on grizzly bear habitats in Valhalla Park in 1983 and in Kokanee Glacier Park in 1984.

Grizzly bear attacks most frequently occur when hikers encounter a grizzly bear suddenly or encounter a bear that has a history of feeding on people's food or garbage (Herrero 1985). Grizzly bears are most likely to be encountered at or near their natural feeding areas. Time budget studies show that grizzlies spend most of their time feeding and resting (Gebhard 1983; Stelmock 1981). Resting areas are usually near feeding areas. Thus an important means to decrease conflicts between people and grizzly bears is by locating trails, camping areas, and mountain huts away from important grizzly bear habitats. Grizzly-human encounters around camping areas and mountain huts are also related to food and garbage storage and to the proximity of these facilities to natural grizzly feeding areas.

The timing of park developments, budget constraint or other factors often prohibit in-depth studies of grizzly bears and their habitats before development begins. In this paper we discuss the usefulness and limitations of a system for rapid field evaluation of grizzly bear habitats. We emphasize the identification of potential feeding areas and their use by grizzlies, although we also discuss denning sites, potential travel corridors, and other habitat parameters. We then show how we applied this information to master planning and location of trails, alpine huts and camping areas in two ecologically similar parks. In this context we compare the applicability of habitat information to an older park with previous development and master planning to a new park with little previous development where grizzly bear habitat information was incorporated into a new master plan.

STUDY AREAS

The study areas were Valhalla Provincial Park (494 km^2) and Kokanee Glacier Provincial Park (256 km^2). Both parks are located in the southern Selkirk Mountains in southeastern British Columbia, north of Nelson, BC. The parks are 15 km apart and are separated by a low valley and the large Slocan Lake.

Although the parks are ecologically similar, they differ substantially in their history, development, and accessibility. Kokanee Glacier Park was established in 1924. Much of the current network of roads and trails was developed by mining activities before and after the park was established. Kokanee is a Class "B" park which allows limited commercial activities (logging and mining), although there has been no logging to date and no mining since 1974. The park encompasses the headwaters of eight different drainages, seven of which have some form of road or trail access into the park. The ease of public access from many directions almost doubled

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visitor use between 1976 and the present. In 1984, approximately 12,300 people visited the park (British Columbia Parks Division 1984). Valhalla Park was established in 1983. It has a limited, primitive, and unmaintained trail system. Few visitors travel its remote wilderness but significant use occurs at low elevations along the shore line of Slocan Lake. Valhalla is a Class "A" park designated for natural landscape representation and limited recreational development. No resource extraction is allowed.

Both parks are in the Interior Wet Belt Zone of the province, which has diverse biogeoclimatic subzones ranging from moist western redcedar (Thuja plicata)-western hemlock (Tsuga heterophylla) in some of the valley bottoms to alpine tundra in the high country (Utzig and others 1983). The damp interior climate fosters a rich diversity of abundant grizzly bear foods in some of the biogeoclimatic subzones of these parks.

Grizzly bears and black bears (U. americanus) are common in both parks. The most abundant ungulate is the mountain goat (Oreamnos americanus), with some mule deer (Odocoileus hemionus), and white-tailed deer (O. virginianus). Columbian ground squirrels (Spermophilus columbianus) and hoary marmots (Marmota caligata) are two of the common small mammals in the high country. Grizzly bears feed on these species opportunistically. Grizzly bear hunting has been allowed in both park areas and continues under existing park policy. Hunter kills, however, have been negligible.

METHODS

We used the transect method of grizzly bear habitat evaluation as described by Herrero and others (1983). Approximately 20 man-days of transect surveys were done in the summer-fall of 1983 in Valhalla Park and 40 man-days in the summer-fall of 1984 in Kokanee Glacier Park.

Transects were routes walked along trails or pathless areas. These transects were usually laid out to sample the apparent bear habitats in an area. These habitats were first determined by preliminary delineation on 1:15,840 air photos and more finely located by inspection in the field. Where a park development was proposed, transects were also laid out to cover these areas. Each transect was divided into a number of segments based primarily on assumed habitats or topographic units. Each transect segment was assigned a number and the route marked on 1:50,000 topographic maps.

Along each transect segment, we subjectively evaluated potential bear foods and their use as well as other bear sign. The evaluation of the food items for habitat potential (capability) involved rating each species along a segment according to high, medium, low, or trace densities. These ratings were relative to its occurrence in other portions of the study area. In making these ratings, the experience of the field worker in the area was very important.

Ratings of potential food items were based on the known diet of grizzly bears in ecologically similar areas of the Selkirk Mountains (Hamer 1974; Mundy 1968; Simpson and others 1984). As the study progressed, the list of potential foods was modified from results of an ongoing feeding site and scat analysis. We rated 30 potential foods, which included corms and roots, green vegetation, berries, and animal matter (table 1).

Along each segment the areal extent of some foods was noted, for example, the size of a patch of mountain huckleberry or the confinement of cow parsnip or common horsetail to a narrow stream margin. Where possible, the areal distribution of foods was marked on 1:50,000 maps and 1:15,840 air photos. Also taken into account were general vegetative characteristics and the apparent ease of digging of the substrate for grizzlies attempting to unearth underground foods such as corms of glacier lilies. Besides the evaluation of foods, the number of diggings, scats, tracks, beds, rub trees, and other sign was recorded. We attempted to indicate age of all bear sign.

The next step was to assign a rating (high, medium, low, or trace) for overall potential and actual use of each habitat or segment for each season (spring, summer, and fall). It was important to rate both potential and use, since use varies from year to year. The habitat potential was based primarily on the relative abundance of food items and the importance of each food for each season as determined by other studies carried out in ecologically similar areas (Hamer 1974; Mundy 1963; Simpson and other 1984) and an ongoing scat and feeding sign analysis. The use for each season was subjectively rated (when possible) on the basis of the quantity, types, and ages of sign. At the end of the field season, the ratings from different transects in a valley or area were subjectively combined to give an overall rating of seasonal potential and use for the valley or area.

We were careful to differentiate sign left by grizzly bears from sign left by black bears. There is little evidence that black bears dig for corms, roots, or ground squirrels (Herrero 1985); therefore all diggings, except those apparently for ants and wasps, were assumed to have been made by grizzlies. Scats and feeding sign on green vegetation were more difficult to differentiate as to species of bear. There are no published criteria for differentiating black bear and grizzly scats (Hamer and others 1981); therefore we used associated signs such as tracks and hairs. Grizzly bear tracks were differentiated from black bear tracks by the longer front claws, lesser arc of the toes and greater chance of the toe imprints being joined (Lloyd 1979). Hairs of grizzlies could be differentiated when they were silver tipped. The elevation of the sign was sometimes used to differentiate because grizzlies tend to range at higher elevations at certain times of the year than do black bears.

Table 1.--Tentative food items of grizzly bears used in data sheet for evaluating grizzly bear habitats

Habitat Evaluation

Transect number:
Date:

Location:

Roots and Corms:	Transect segment							
Glacier lily (Erythronium grandiflorum)								
Western spring beauty (Claytonia lanceolata)								
Bog orchid (Habernaria spp.)								
Cicely (Osmorhiza spp.)								
Green Vegetation:								
Horsetail spp. (Equisteum arvense)								
Grasses (Gramineae)								
Sedges (Carex and others)								
Mountain sorrel (Oxyria digyna)								
Indian hellebore (Veratrum viride)								
False Solomon's seal (Smilacina racemosa)								
Twisted stalk (Streptopus amplexifolius)								
Meadow rue (Thalictrum occidentale)								
Lady fern (Athyrium felix-femina)								
Stinging nettle (Urtica lyallii)								
Cow parsnip (Heracleum lanatum)								
Queen Anne's lace (Angelica arguta)								
Lovage (Ligusticum canbyi)								
Berries:								
Mountain huckleberry (Vaccinium membranaceum)								
Blue huckleberry (V. ovalifolium)								
Swamp gooseberry (Ribes lacustre)								
Sitka mountain ash (Sorbus sitchensis)								
Black elderberry (Sambucus melanocarpa)								
Red raspberry (Rubus idaeus)								
Devil's club (Oplopanax horridum)								
Bracted honeysuckle (Lonicera involucrata)								
Animal Matter:								
Ants								
Columbian ground squirrel								
Hoary marmot								
Deer								
Mountain goat								

We then related available information on grizzly bear habitats to existing and proposed trails, camping areas and mountain huts by overlaying both on 1:50,000 topographic maps. We subjectively decided the potential for grizzly-people conflicts. Although grizzly habitat information was used to rate hazards, other factors were also considered: cumulative developments, visitor use trends, previous garbage-food problems, timing of people's use of the area versus timing of grizzly's use, previous bear sightings and encounters, possible travel corridors, dens, degree of visibility in the habitat for sighting bears, and associated noise such as nearby mountain creeks.

RESULTS AND DISCUSSION

To illustrate our work we present examples of applying the transect method to different areas and situations in Kokanee and Valhalla Parks (McCrory 1984, 1985).

Master Planning

In Kokanee Glacier Park the draft master plan was prepared in 1981 after most park development had taken place but several years before the study of grizzly bear habitats began. As part of the master plan, areas were zoned for intensive, backcountry, and wilderness use.

Information we collected subsequently on grizzly bear habitats showed that some important habitats overlapped with areas zoned for intensive and backcountry visitor use, whereas others did not and fell within the wilderness category (fig. 1).

In one area zoned for backcountry use (Coffee Creek) and proposed enhancement of a historic trail, it was found that the trail corridor passed through a mosaic of habitats of high spring through fall capability for grizzlies. Grizzly use appeared high for summer and fall. It was recommended that the area be rezoned as wilderness and the trail closed.

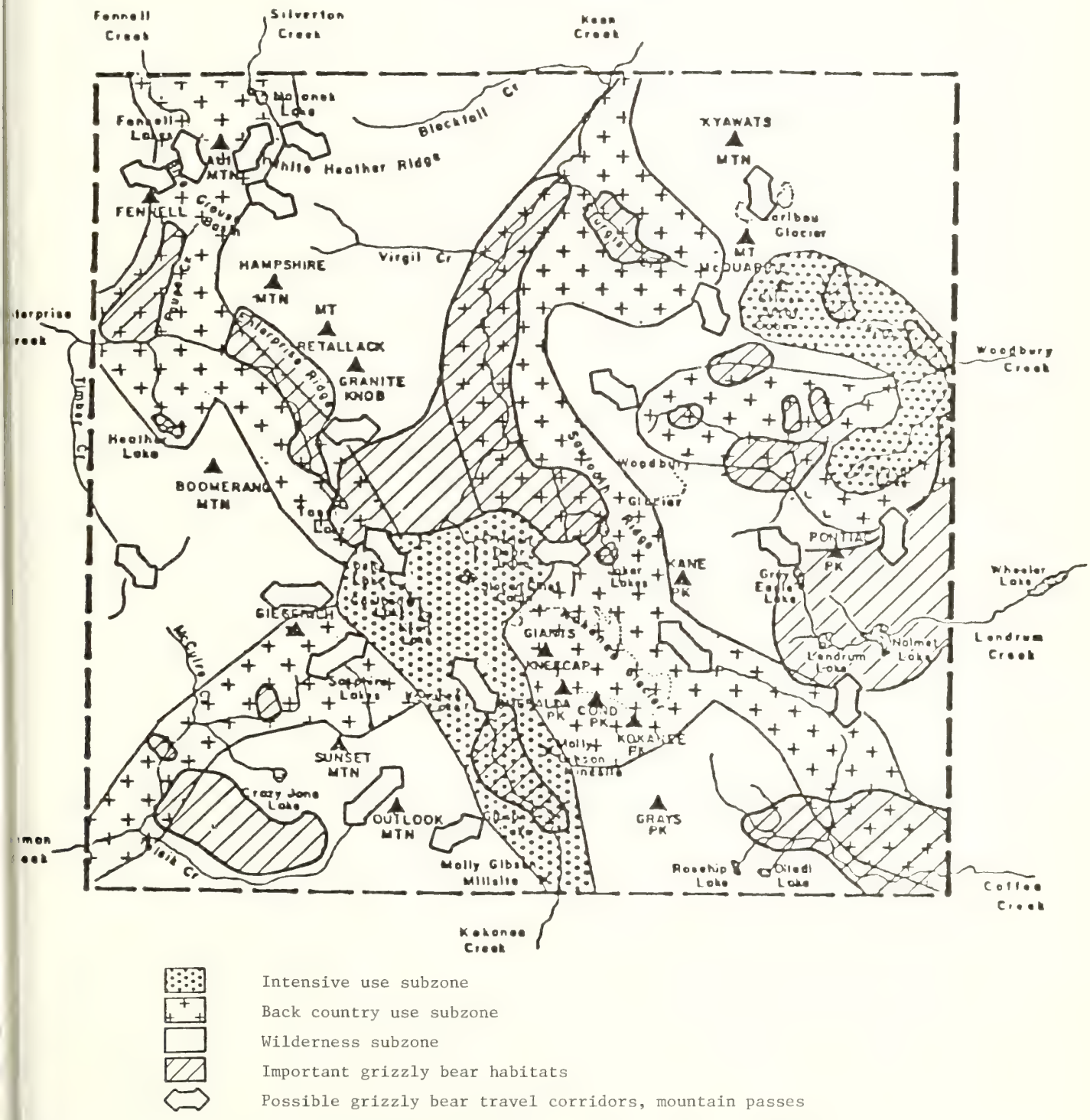


Figure 1.--Important grizzly bear habitats and zoning in 1981 master plan for Kokanee Glacier Provincial Park. Scale: 1 cm = 1 km.

The main area of conflict identified in Kokanee Glacier Park was in the central region, where master plan zoning for intensive use overlapped with major components of grizzly bear habitats. Within this intensive use zone important habitats included a large area of slide paths and wet meadows that were used in summer by as many as four grizzlies and an upland area that appeared to be an important travel corridor and Columbian ground squirrel feeding area for grizzlies. Five mountain passes converge in this upland area. Just to the north of the area zoned for intensive use was a major huckleberry feeding area where there have been sightings of as many as five grizzlies.

Road access to the central region facilitates high visitor use. A network of hiking trails, campsites, and a mountain hut attract increasing back country use that overlaps with important grizzly habitats. Since 1976, back country visitor use has nearly doubled to 3,263 visitors per year and there have been at least 12 non-injurious incidents between park visitors and mother grizzlies. In Glacier Park, MT, Martinka (1982) has documented the increase in human-grizzly confrontations as human visitation increases. There is serious concern that zoning the central region of Kokanee Glacier Park for intensive use and encouraging the introduction of more novices to the wilderness will eventually lead to injurious confrontations between people and grizzly bears.

We recommended that the central region of Kokanee Glacier Park be rezoned when the master plan is revised and that the new zoning recognize the fairly high bear hazard. Other areas of lower bear hazard were identified in Kokanee Glacier and Valhalla Parks. These areas could be zoned for more intensive visitor use.

For the new Valhalla Park, all information on grizzly bear habitat was integrated into an ongoing master plan. Important grizzly habitats were incorporated into a "natural feature subzone" that designated special wildlife habitats. Two major valleys identified as having extensive grizzly habitats in all seasons were designated as natural feature subzones where no development would take place. In other instances, proposed developments were generally planned to avoid important grizzly habitats; some existing developments such as trails were allowed where the hazard could be controlled by methods such as trail rerouting.

Mountain Huts

Mountain huts are a form of public backcountry accommodation in Valhalla and Kokanee Glacier Parks. Although they provide safer overnight facilities in grizzly country, huts tend to become destination points that increase backcountry use.

In Valhalla Park, grizzly bear habitats in the area of one proposed and one existing hut were compared to illustrate the usefulness of the transect method of grizzly habitat evaluation. Habitat transects in the area of a proposed hut in the headwaters of Nemo Creek showed the surrounding alpine meadows to have a high habitat capability for all seasons because of high densities of glacier lily, grasses, and sedges. Meadows there were extensively dug by grizzlies feeding on glacier lily corms and, to a lesser degree, on Columbian ground squirrels. We found no suitable alternate hut locations and recommended that the hut not be built. In Mulvey Basin a mountaineering club built a plywood hut in the 1960's. Although the surrounding alpine meadows were shown to have a low habitat capability and use, the hut bordered the main valley, which had a high capability and use. It was recommended that a more suitable location for a replacement hut was higher in the alpine basin and thus farther from the prime habitat.

Camping Areas

In Kokanee Glacier Park, one example shows the usefulness of the transect method in helping to evaluate the potential for grizzly bear-people conflicts at existing camp sites. Kokanee Lake camp site is located in the central region zoned for intensive use. Habitat transects of the surrounding subalpine meadows showed a low summer and fall habitat potential. There was a trace of grizzly use mostly comprised of diggings for glacier lily corms at the camp site; however, the camp site is only 0.25 km from a grizzly summering area with high habitat potential and use. It is also located in a mountain pass that grizzlies apparently use as a travel route. In 1982 a subadult grizzly that had apparently been digging for glacier lily corms and garbage buried at this camp site dragged a pack away from a tent; as a result the camp site was closed permanently in 1984.

In Valhalla Park, two examples demonstrate the usefulness of information on grizzly bear habitats in locating new back country camp sites. A proposed group camp site in alpine meadows at Gwillim Lakes was approved when transects showed the large meadows have only a trace capability to support grizzlies. A proposed camp site at a lake 6 km down the valley, however, was not advised because it was in an area with high summer capability and use. Wet meadows around the lower lake shore produce high densities of horsetail, sedges, and grasses. Beds, scats and tracks showed a high summer use by grizzlies, including a mother with young.

Trails

Grizzly bear habitat information was useful in identifying potentially hazardous areas along proposed or existing trails. Although encounters can occur along any point of a trail, we believe that they are most likely to occur near grizzly feeding areas that are crossed by the trail. Obviously, the larger the feeding areas crossed and the higher the grizzly use at different seasons, the higher the hazard. Following are three examples of trail situations.

In Kokanee Glacier Park, the trail to Silver Spray Hut passes through large areas of mature forest with an overall trace-low habitat potential and grizzly utilization; however, the trail passes for 100 m through a slide path that has a moderate grizzly potential for all seasons. Grizzly use of the 100 m segment appeared moderate in late summer and fall. Since this slide path concentrated feeding activities of grizzly bears more than other habitats crossed by the trail corridor, encounters between people and grizzly bears are most likely to occur at this site. Recommendations made to reduce the bear hazard included clearing overgrown areas of the trail through the slide to 3 to 4 m wide and straightening the trail to eliminate blind corners. Small warning signs posted at either side of the slide path and at the trail register were also advised.

A different problem exists on the Joker Millsite-Slocan Chief Cabin Trail in Kokanee Glacier Park. This well-used trail passes for 3 km through a major huckleberry feeding area for grizzlies. Since 1976, there have been at least four noninjurious incidents between hikers and grizzlies on this trail. In 1984, a seasonal trail closure was instituted throughout the huckleberry season. Other trails provide alternative access and present a lower risk of encounters.

In Valhalla Park, habitat transects along the access trail to Mulvey Hut showed that the trail passes for 3 to 4 km through a mosaic of habitats that have a high capability. These habitats include wet meadows interspaced in forest, slide paths and an old burn. Together these areas produce abundant and varied grizzly foods. Scats and signs of feeding on green vegetation, glacier lily corms, and huckleberries indicated high grizzly use for all seasons. Because the trail could not practically be rerouted to avoid this large hazardous area, it was abandoned in favor of alternative access routes through other valleys.

CONCLUSIONS

This study shows the usefulness of the transect method of habitat evaluation when time and budget constraints preclude the use of important but expensive long-term methods of determining grizzly bear habitat availability and use. We believe that the transect method should only be used, however, by experienced researchers and only where reliable information on grizzly bear food habits is available from an ecologically similar area. An ongoing analysis of bear scats and feeding signs in the study area is also useful in refining food habit information as the study progresses.

The information on grizzly bear habitats provided by the transect method can be integrated into park master plans. Zoning areas for different levels of visitor use can help reduce chances of conflicts with grizzlies. When grizzly bear habitat information is not used in master planning, visitor use may increase in important grizzly habitats, increasing the chances of incidents between humans and bears.

The transect method is also a quick, cost-efficient, and reliable means to incorporate information on grizzly bear habitats into the planning and safer location of trails, camping areas, and mountain huts before they are built. Where such developments already exist, the transect method is useful in evaluating the degree and location of hazards and making management recommendations that endeavor to reduce people-grizzly conflicts.

The transect method is useful in covering large areas and in locating important feeding areas in microhabitats that are too small to be detected from air photos. As well, the transect method relates the importance of habitats to the seasonal diet of grizzlies, streamlining the use of such information for park planning and management.

One serious deficiency of the transect method is that it uses information on existing vegetation to evaluate grizzly habitats in relationship to permanent park facilities. This does not allow for long-term changes in habitats and bear foods, for example, those resulting from wildfires that could substantially affect grizzly bear use of the area of a park development. Other limitations of the transect method of habitat evaluation are considerable. Important habitats can be missed. The subjective methods employed can also lead to errors in judgment. As well, interpretation of grizzly bear habitat use and people-bear hazards is limited by lack of baseline information on the bears' use of different habitats, movement patterns, sex and age differentiation of habitat use, changes in habitat use because of population fluctuations, and other factors. However, the results of this study at least crudely evaluate grizzly bear habitat use at a level that is useful in making timely planning and management decisions to attempt to reduce human-grizzly conflicts. Longer term studies involving radio-telemetry and more in-depth habitat delineation were recommended in both parks to expand the data base and refine strategies to manage human-grizzly conflicts.

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Session II—Habitat Mapping and Evaluation

Chaired by:

Glenn Erickson, Chief, Statewide and Special Projects, Montana Department of Fish, Wildlife, and Parks, Helena, MT

Don Despain, Research Biologist, National Park Service, Yellowstone National Park, WY

GRIZZLY BEAR HABITAT COMPONENT MAPPING IN THE NORTHERN REGION

Rose Leach

ABSTRACT: The U.S. Department of Agriculture, Forest Service, Northern Region's grizzly bear habitat component mapping project comprises three northern ecosystems: Northern Continental Divide, Cabinet-Yaak, and Selkirk Mountains. Mapping objectives are to (1) better describe National Forest occupied grizzly bear habitat and management situations 1, 2, and 3 areas within occupied habitat, (2) coordinate with other resource management activities, (3) develop habitat improvement projects, (4) analyze relative habitat capabilities, and (5) provide data for cumulative effects analysis projects. Maps show best estimates of areas important to the bear but not the entire picture of grizzly bear habitat. Advantages are map accuracy, visual presentation, and adaptability to future research innovations.

PRESENT PROGRAM

Goals and Objectives

Grizzly bear habitat component mapping is one of the U.S. Department of Agriculture, Forest Service, Northern Region's contributions toward grizzly bear recovery. The objectives of component mapping are to (1) better describe National Forest occupied grizzly bear habitat (U.S. Department of the Interior, Fish and Wildlife Service 1982) and management situation 1, 2, and 3 areas (USDA Forest Service and USDI National Park Service 1979) within occupied habitat; (2) coordinate with other resource management activities; (3) develop habitat improvement projects; (4) analyze relative habitat capabilities; and (5) provide data for cumulative effects analysis programs.

Methods

The Region's project area includes three northern ecosystems: Northern Continental Divide (NCD), Cabinet-Yaak (C-Y), and Selkirk Mountains (SM) (fig. 1). Our program there involves mapping of seven National Forests (including one in the Pacific Northwest Region), located in Washington, northern Idaho, and western Montana. Portions of the Northern Region in the Yellowstone ecosystem are included in another paper.

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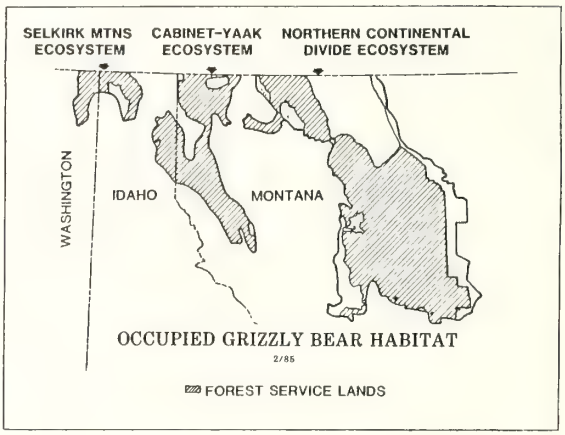


Figure 1.--National Forest lands in grizzly bear-occupied habitat.

Because bears have only 6 to 9 months to eat enough to sustain themselves for an entire year, one approach to managing for bears is to manage for productive feeding sites. Servheen (1981) indicates that bear movements within home ranges are dictated by seasonal availability of foods and denning sites. Thus, researchers have developed grizzly bear habitat component concepts based on key bear foods and denning requirements (Madel 1982; Servheen and Lee 1979; Servheen 1981).

In the Northern Region mapping program, grizzly bear habitat components are consistently recognizable sites with a structural or vegetative identity of value to grizzly bears (USDA Forest Service 1983). Many components apply to all three northern ecosystems; some are unique to certain areas. Components are based on vegetation plots (Pfister and others 1977) and are described in detail in map project writeups, including Madel (1982) for the Cabinet Mountains, MT; Houghton and others (1983) for the Purcell and Cabinet Mountains, ID; Leach and Tirmenstein (1983) for Lolo National Forest, MT; Berner and others (1984) for Helena National Forest, MT; Tirmenstein and Cline (1984) for Swan-Scapegoat, MT; and Ash (1985) for the Whitefish Range, MT. Concurrent bear telemetry studies (conducted by other groups) and bear sighting and sign information from mapping crews further validate habitat components.

Each component is assigned a season or seasons of use, based upon the bear food plants present. Forest Service biologists and other users of component maps are primarily interested in four classes of bear foods: (1)

grasses and sedges used in early spring and at high elevations in summer (for example, Grammineae and Carex spp.); (2) wet site forbs used in spring (for example, umbels such as Angelica spp., Ligusticum spp., and Heracleum lanatum); (3) roots and corms used in spring and summer (for example, Claytonia lanceolata and Erythronium grandiflorum after it goes to seed); (4) fruits used in fall (for, example, Vaccinium spp., Sorbus scopulina, Shepherdia canadensis, and Amelanchier alnifolia). The project writeups previously listed include area-specific key bear foods.

Most components are located in forest openings, although timbered areas are also important to bears. To date, mappers have no simple and accurate method to stratify timbered areas because most components under timber canopies are not easily recognized by aerial photo interpretation. Currently, crews are able to map only those timbered components that they happen to encounter in the field. The Northern Region is investigating other mapping techniques (LANDSAT, high-elevation infrared photography, or other remote sensing techniques) to facilitate mapping forested areas. If promising, these methods could facilitate mapping in wilderness, timbered areas, management situation 2 and 3 areas, and previously unmapped areas including other ownerships.

Components are usually named after the hierarchy of dominant vegetation within them, followed by a site description. Examples are mixed shrubfield/snow chute and mixed shrubfield/cutting unit.

Maps are digitized and stored on a computer coordinate system, so that all maps are oriented to each other. A user can retrieve the information by land section, by bear unit, or by ecosystem, for example. The Region will use some type of Geographic Information System (GIS) to organize the digitized information. The Washington Office is evaluating which GIS the Forest Service will use.

Results

The Northern Region contains about 43 percent of all occupied grizzly bear habitat in the lower 48 States (fig. 2; USDI Fish and Wildlife Service 1982), most of which occurs in the three northern ecosystems: NCD, C-Y, and SM.

In summer 1984, the Region employed 23 seasonal field technicians to map components, and I expect a similar number for 1985. Qualifications for mappers include plant identification skills and ability to use aerial photographs and topographic maps.

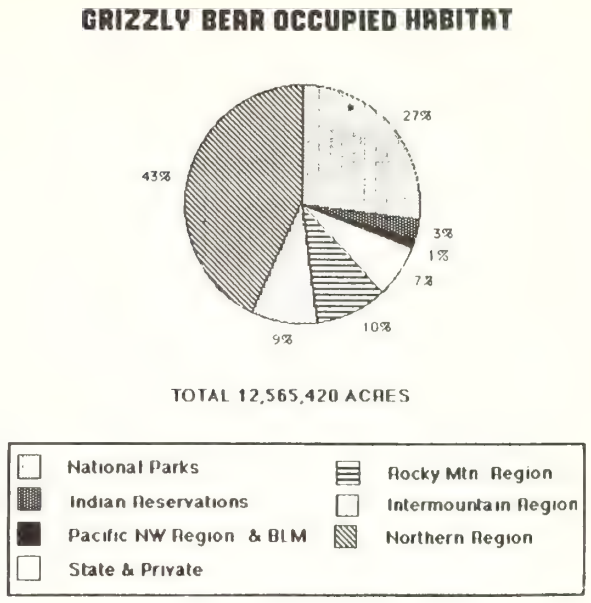


Figure 2.--Ownership or management agency of grizzly bear-occupied habitat. "Regions" refer to National Forest System regions.

After summer 1985, the Region expects to have completed all mapping in the C-Y and SM ecosystems and about 30 percent of the NCD ecosystem (fig. 3). Most of the remaining 70 percent of the NCD ecosystem to be mapped is in wilderness (fig. 4). The Region plans to complete the nonwilderness portion of the NCD ecosystem in summer 1987 and the wilderness portion in 1991. If workers can use more sophisticated mapping methods, the wilderness portion will be finished much sooner.

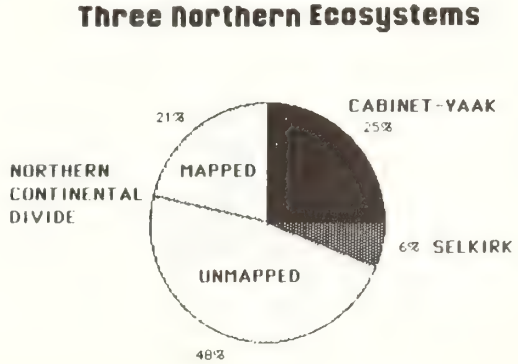


Figure 3.--Grizzly bear habitat component mapping accomplishments through 1985.

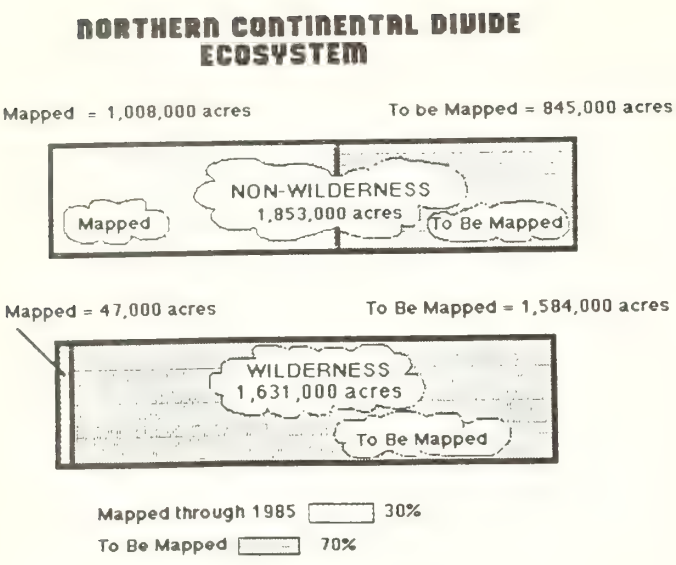


Figure 4.--Grizzly bear habitat component mapping accomplishments in the Northern Continental Divide Ecosystem.

FUTURE DIRECTION

Component maps are evolving into more complete vegetation maps which display all openings, rather than displaying only the most productive sites as originally described by Madel (1982). Mappers will differentiate openings by labeling them according to the number and percent coverage of key bear foods present. Each ecosystem will use its own list of key bear foods, based on data from the nearest research project. In areas with few local bear-food studies, mappers will record the percent coverage of the predominant plant species in the opening. Thus, component values may be assigned once biologists agree on which plants are key bear foods in the area. Because vegetative data are recorded on permanent field plot sheets, the relative value of each area can be reassessed as new bear-use data become available from research projects. Mapping all openings has several advantages: (1) mapping is repeatable; (2) openings are distinguishable; (3) maps are more complete.

As mappers encounter areas that do not seem to fit descriptions of previously described components, they will take vegetation plots (Pfister and others 1977) to describe the area and tentatively call it a new component. The Region is now analyzing all the plot forms, by ecosystem, to determine if mappers have taken adequate data to describe both old and new components. Decisions on component definitions are made at the Regional office, based on this analysis of vegetative plot forms.

Grizzly bear component mapping is not a one-time, static effort. As in other forms of Forest Service vegetative mapping (for example, timber and range), the maps will be periodically updated. The National Forests involved expect to do this every 5 to 10 years.

Biologists and others concerned with component maps welcome further refinement of the mapping system. For example, Jon Almack's current study in the Idaho Panhandle National Forests has prompted the Forest to include an additional area into the SM mapping project. The reason: a telemetered bear from the study extensively used an area not previously designated for component mapping.

Shortcomings and Advantages

To properly interpret maps, users must keep in mind the limitations of the mapping system. In general, maps show our best estimate of "red flag" areas that are important to the bear but not the entire picture of grizzly bear habitat. For example, maps do not display "space" as an essential part of grizzly bear habitat. In addition, the concept of cover is not addressed. As mentioned previously, components under tree canopies are underestimated. When mapping shrubfields, mappers unfortunately have no indication of how good or poor berry production may be. Also, component mapping is a very time-intensive process and is especially slow where access is poor, as in wilderness. Therefore, to better understand the mapping process, we encourage biologists and other District personnel to talk with and occasionally accompany crews in the field.

Initially, habitat component maps are intended to illustrate general information on the potential value of a given area to provide forage or denning habitat. When a specific project is proposed, District biologists must visit the site to determine the actual values of the area and develop any necessary constraints or coordination measures to protect those values. Eventually, when biologists from each ecosystem develop appropriate models, component maps will provide the vegetative base to run the cumulative effects analysis, as discussed in another symposium paper.

One advantage to intensive ground mapping for components is that maps are presumably very accurate. In addition, component maps are a good tool for visually displaying grizzly bear habitat and are necessary for cumulative effects analyses. Finally, the component mapping system is robust enough to permit incorporation of future research findings and more sophisticated mapping techniques.

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GRIZZLY BEAR HABITAT IN THE KIMSQUIT RIVER VALLEY, COASTAL BRITISH COLUMBIA: CLASSIFICATION, DESCRIPTION, AND MAPPING

Allen Banner, Jim Pojar, Rick Trowbridge, and Anthony Hamilton

ABSTRACT: The Kimsquit River valley, a ruggedly mountainous watershed on the central mainland coast of British Columbia, is the location of an interagency grizzly bear research project initiated in 1982. The project has as one objective the identification of seasonal habitat requirements of coastal grizzlies. This requires habitat classification, description, and mapping. The intensively studied portion of the valley occurs along the lower river and includes about 70 percent of the relocations of two intensively monitored, adult female grizzlies equipped with radio transmitters. Habitat classification for the study area (excluding the estuary) was linked to an existing, climax-based ecological classification, modified to accommodate the extensive seral vegetation that has developed after geomorphic and logging disturbances. Ecosystem description and mapping were based on interpretation of pretyped, 1:20,000 color aerial photography and on ground sampling involving transects and detailed and reconnaissance-level plots. The map area was approximately 5 000 ha and included seven climax forest ecosystem units and two nonforested units--wetlands and avalanche tracks. The forested units were designated according to eight successional stages based on vegetation physiognomy and were also subdivided into 19 variations based on species composition. Although vegetation was primarily used to delineate polygons, a landform/soil component was also included in the map units. A total of 419 polygons were mapped as pure or complex units. The maps were digitized and entered on a computer-assisted mapping system, so that derivative maps for wildlife interpretations could be produced. Our work provides a framework for further analysis and evaluation of grizzly habitat by the wildlife biologists in the research team.

INTRODUCTION

One of the major wildlife management problems in British Columbia centers on coastal grizzly bears (Ursus arctos) and their habitat. In 1982, the British Columbia Ministries of Environment and Forests started a research project in the Kimsquit River valley to address this problem (Archibald and Hamilton 1982). One project objective has been to identify seasonal habitat requirements of coastal grizzlies. This requires habitat classification, description, and mapping. When British Columbia Forest Service research staff were asked to do the work, we decided to use an existing ecosystem classification of the region (Yole and others 1982) as a framework for the study.

Recent studies describing techniques for mapping grizzly bear habitat in the Rocky Mountains have dealt with interior mountain systems where large areas of grizzly habitat occur in alpine and subalpine zones (Craighead and others 1982; Hamer and Herrero 1983). These studies have only limited application to coastal mountain valleys such as the Kimsquit, where grizzly habitat occurs predominantly below treeline and is largely concentrated in valley-bottom ecosystems associated with important salmon rivers.

We initially stratified the Kimsquit watershed into three study areas--the estuary, the lower valley, and the upper valley--based on biogeoclimatic considerations, workload, and concentration of effort by the bear biologists. A private consultant classified and mapped the estuary (Clement 1984b) and the upper valley (Clement 1984a) separately. We studied the lower valley below 500 m, which includes about 70 percent of the relocations of two intensively monitored, adult female grizzlies equipped with radio transmitters.

We needed to modify and expand the existing, climax-based ecosystem classification for the lower valley to accommodate the extensive seral vegetation resulting from past geomorphic and logging disturbances and also because we considered description and mapping of seral ecosystems essential for wildlife interpretations. Most forest ecosystem research in British Columbia has been done in mature or climax stands. A few coastal studies have dealt primarily (Mueller-Dombois 1959; Houseknecht 1976; Klinka and others 1985) or secondarily (Inselberg and others 1982) with seral forest vegetation. Most forest ecologists in northwestern North America have used stand age, composition, structure, and cover to stratify structural or developmental stages in both seral

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and mature forests (for example, Thomas 1979; Arno 1982; Henderson 1982; Alaback 1984), and we followed their lead.

The major objective of this paper is to present an approach to ecosystem classification and mapping that provides a framework for evaluating coastal grizzly bear habitat. A detailed description of the classification and mapping project can be found in Banner (1985).

TAXONOMIC CONSIDERATIONS

Nomenclature follows Taylor and MacBryde (1977) for vascular plants (both scientific and common names); Crum and others (1973) for mosses; Stotler and Crandall-Stotler (1977) for liverworts; and Hale and Culberson (1970) for lichens. Soil taxonomy follows Canada Soil Survey Committee (1978). Humus form terminology is after Klinka and others (1981).

STUDY AREA

The Kimsquit River valley is a ruggedly mountainous, 104 000 ha watershed on the central mainland coast of British Columbia (fig. 1). The mouth of the river, at the head of Dean Channel (a huge fiord; fig. 2a), lies 60 km north - northwest of Bella Coola and 120 km inland from the open Pacific Ocean. The watershed is bounded to the east by Tweedsmuir Provincial Park.

Three biogeoclimatic zones (Krajina 1965; Pojar 1983) occur within the valley: the coastal western hemlock zone (CWH) at lower and montane elevations, the subalpine mountain hemlock zone (MH), and the alpine tundra zone (AT). The CWH in the Kimsquit is represented by two subzones: the midcoast drier transitional (CWHh) and the wetter maritime (CWHi). This paper deals only with the CWHh, which occupies the lower 20 km of the valley (Yole and others 1982), extends from sea level to 400 to 500 m elevation, and defines the 5 000 ha study area (fig. 1).

The lower Kimsquit valley has a humid suboceanic climate. Moist Pacific air masses lose much of their precipitation by the time they reach the innermost ranges of the Coast Mountains, yet the moderating coastal influence prevails even this far inland. The closest suitable long-term climate station is at Kemano, 90 km to the northwest. Based on 30-year normals (Environment Canada 1980), Kemano has a mean annual temperature of 6.5 °C. Total annual precipitation averages 1 867 mm with 11 percent falling as snow. June is the driest month, October the wettest. Strong winds, especially during the fall and winter, are a significant climatic feature.

The Kimsquit watershed is part of the Kitimat Ranges of the Coast Mountains (Holland 1976). Topography is very rugged, with mountains rising steeply from the valley floor near sea level to over 2 000 m. Plutonic rocks, mainly quartz

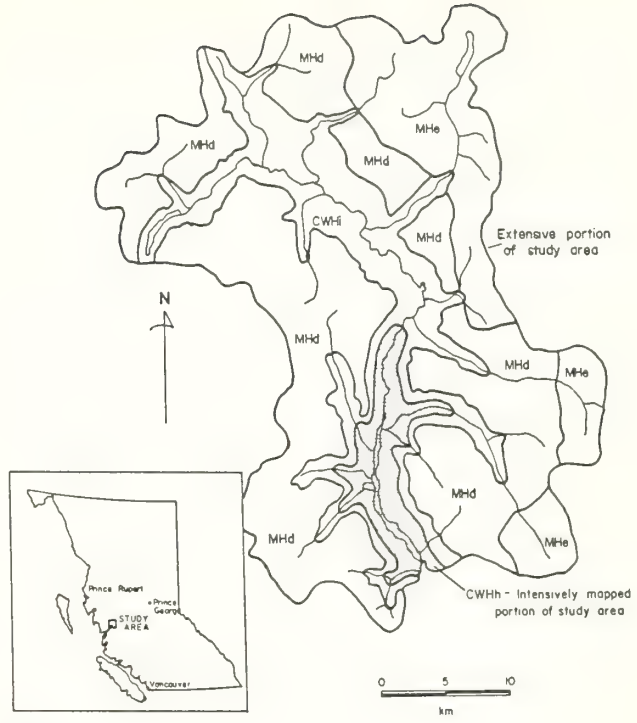


Figure 1.--Map of forested biogeoclimatic zones of the Kimsquit River Valley showing location of the study area. Abbreviations: CWH, coastal western hemlock zone; CWHh, mid-coast drier transitional subzone; CWHi, wetter maritime subzone; MH, mountain hemlock zone; MHd, coastal subzone; MHe, transitional subzone.

diorites and diorites, dominate the bedrock geology of the study area, although metavolcanic greenstone is common on the west side of the valley (Baer 1973).

Landforms and soils are generally typical for the Coast Mountains (Jungen and Lewis 1978). Glacial landforms (including morainal, glaciofluvial, and glaciolacustrine deposits) occur, but the majority of the terrain has been more recently modified by fluvial and colluvial processes and by accumulation of surface organic matter. Fluvial soils are mainly Regosols and Brunisols; colluvial soils are mainly Podzols and Brunisols with some Folisols; soils developed in glacial till typically are Podzols. Soil textures are relatively coarse, generally sandy to loamy; skeletal soils are common. Mor humus forms dominate the forested slopes, whereas fluvial ecosystems typically have Moders and Mulls.

Coniferous forests dominate the vegetation (fig. 2). Climatic climax or zonal forests consist chiefly of western hemlock (Tsuga heterophylla) but contain variable amounts of western redcedar (Thuja plicata) and Douglas-fir (Pseudotsuga menziesii). Dry forests are usually mixtures of western hemlock and Douglas-fir, sometimes with shore pine (Pinus contorta var. contorta). Amabilis fir (Abies amabilis) and Sitka spruce (Picea sitchensis) join western hemlock, redcedar, and sometimes Douglas-fir on

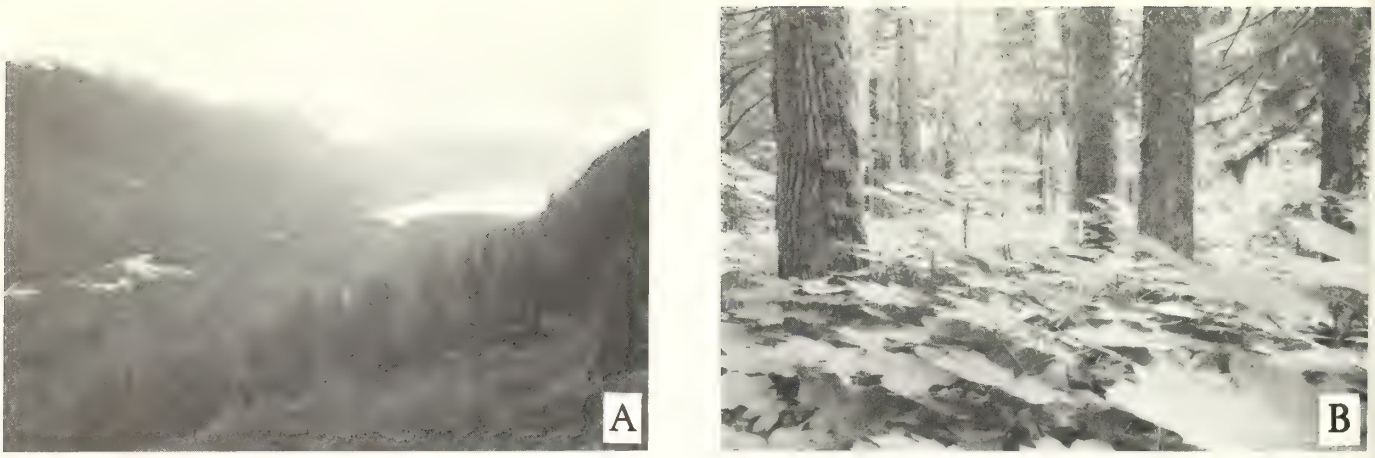


Figure 2.--Photos of the Kimsquit Valley study area. (A) View looking southeast over river mouth and the head of Dean Channel. (B) Black cottonwood-Sitka spruce-devil's club forest community common on the Kimsquit flood plain.

moisture-receiving sites of lower slopes. The most productive forests are the alluvial spruce types on the flood plain. These stands were mostly logged about 1918 (Hamilton 1983); consequently, the lower flood plain presently is dominated by deciduous forests of red alder (Alnus rubra) and black cottonwood (Populus balsamifera ssp. trichocarpa), as well as mixed deciduous/coniferous stands (fig. 2b). Shrub- and herb-dominated communities occur mostly on avalanche tracks, river bars, and recent clearcuts. These clearcuts are the result of logging operations that commenced in 1980 and have continued intermittently to the present, on the west side of the valley.

METHODS

Classification Methods

Refining of the existing climax-based biogeoclimatic classification for the CWHh (Yole and others 1982) and characterizing of ecosystem units involved sampling the range of climax and seral ecosystems in the lower Kimsquit Valley.

Overstory and understory species composition, percentage cover, and vigor, soil profile and site descriptions; and tree mensuration data were collected from a total of 89 plots ranging in size from 300 to 500 m^2. Sampling methods mainly followed those outlined in Walmsley and others (1980). In addition, detailed observations of phenology and berry abundance were made for taxa identified as grizzly bear food plants by the wildlife biologists.

Ecosystem data from the sample plots were summarized on computer-generated tables (Klinka and Phelps 1979; Meidinger and others 1983). With the aid of these computer programs, we used the subjective Braun-Blanquet tabular comparison method (Westoff and van der Maarel 1978) to compare and rearrange plots and ultimately group them into ecosystem units (Pojar 1983).

Mathematical ordination of the vegetation data using the computer program DECORANA (Hill 1979) was also applied to clarify relationships among the sample plots.

A table of prominence values was produced to summarize species cover and constancy for each of the ecosystem units. Prominence values (pv's) were calculated by multiplying each species' mean cover by the square root of its percent frequency among the plots of an ecosystem unit (pv = mean cover x $\sqrt{\text{frequency}}$).

Three categories were used to classify and map climax and seral vegetation: the ecosystem association, successional stage, and variation.

We used the ecosystem association as defined by Pojar (1983): "All ecosystems capable of producing vegetation belonging to the same plant association at climax." The ecosystem association therefore describes the climax potential of an ecosystem regardless of the existing seral plant community.

The category of successional stage describes the present physiognomic or structural development stage of the ecosystem association without reference to species composition. The eight recognized successional stages are summarized in table 1.

We used the variation to further subdivide ecosystem associations into community types based on their present species composition. Some variations may represent minor deviations from the central concept of a climax association, whereas others describe distinct plant communities representing seral stages of associations. This is a broader definition of the variation than that of Pojar (1983) and is conceptually similar to the seral association of Klinka and others (1985).

Closely related successional pathways may be associated with two or more ecosystem associations having similar moisture and

Table 1.--Successional stage categories used to classify and map ecosystems in the lower Kimsquit valley

Category		Description
A.	Nonvegetated or bryoid	Initial stage in primary or secondary succession; little or no residual vegetation except bryophytes and lichens.
B.	Herb pioneer seral	Early successional stage dominated by herbaceous vegetation; some invading or residual shrubs and trees may occur (less than 10 percent cover).
C.	Shrub-seedling pioneer seral	Early successional stage dominated by shrubby vegetation; tree cover less than 10 percent but seedlings and advanced regeneration may be abundant.
D.	Pole-sapling	Midsuccessional stage beginning when young trees (saplings) extend into tall shrub layer (greater than 2 m tall) and crown cover exceeds 10 percent; late in this stage vertical crown differentiation begins, as does self-thinning and pruning; a second shade-tolerant tree species may have begun establishment; understories become poorly developed as stand densities increase.
E.	Mature seral	Late successional stage beginning when initial shade-intolerant trees reach maturity; a second cycle of more shade-tolerant trees has usually become established in understory; openings in the canopy result from death of mature individuals; understories usually well developed.
F.	Young climax	Young stands (40 to 80 years old) dominated by climax (shade-tolerant) species in both the overstory and understory; even- or uneven-aged stands, depending on site history; understories poorly to moderately well developed.
G.	Mature climax	Mature stands (80 to 150 years old) comprised of climax tree species in all tree and regeneration layers; these stands are usually uneven aged and structurally heterogenous; understories usually patchy.
H.	Old growth	Very old (150 to 250+ years old), all-aged, structurally complex stands comprised mainly of climax tree species, although old seral remnants may still be present in upper canopy; standing snags and rotting logs on the ground are typical; understories patchy.

nutrient regimes. Thus, seral variations may not be unique to just one climax association (cf. Huschle and Hironaka 1980). For example, the flood plain spruce-devil's club (Oplopanax horridus) association and the devil's club-fern association share many seral variations.

The ecosystem classification outlined above relies mainly on vegetation to characterize units. Although some ecosystem associations, especially those of the driest and wettest habitats, encompass a narrow range of edaphic characteristics, the more widespread associations occur on a variety of landform and soil types, all sharing similar moisture and nutrient regimes. We considered it important to recognize and map contrasting edaphic characteristics because of their potential effect on successional development and on the response of the ecosystem to external disturbances. We used landform/soil types to denote this component of the mapping units.

Mapping Methods

We mapped the area using 1:20,000 color aerial photography (1982 flight line BCC312). Photo interpretation was based on vegetation and physiographic features, however, polygon boundaries were drawn primarily to represent changes in vegetation. Although landform/soil boundaries often coincided with vegetation boundaries, it was common for two adjacent polygons to have the same landform/soil component.

Minimum polygon size was 0.25 cm^2, which at 1:20,000 represents 1 ha on the ground.

We did "ground-truthing" of pretyped aerial photographs along transects that crossed a maximum number of polygon boundaries. Access was by truck and logging road on the west side of the valley, by boat along the lower portion of the river, by helicopter, and on foot. Polygon boundaries and designations were verified by detailed plot sampling, less detailed polygon inspections, rapid observations along the transects, and, in parts of the lower flood plain, by hovering in a helicopter approximately 30 m above the trees. Field sampling was carried out over the summer of 1983 and required 97 person-days of labor.

After completing the field work, we fixed polygon boundaries and map labels on the aerial

photographs and then transferred them using an epidiascope to a 1:20,000 planimetric base map. British Columbia Ministry of Environment personnel digitized the two map sheets that include the majority of the intensively mapped study area (approximately 4 500 ha) and entered them on the Computer Aided Planning Assessment and Map Production System (CAPAMP). Derivative and interpretive maps for wildlife habitat and other resource applications, as well as summaries by area and frequency of occurrence for each ecosystem unit and landform/soil type, can be produced by this computerized mapping facility.

Map Unit Symbols

We constructed map unit labels using the ecosystem unit and landform/soil type components seen in figure 3. A maximum of three ecosystem units and landform/soil types may be included in a polygon label. An ecosystem unit must occupy at least 5 percent, and a landform/soil type 10 percent, of the polygon to be included in the map symbol. At 1:20,000 and at the sampling intensity achieved in this study, however, polygons may contain up to 15 percent inclusions not denoted in the map symbol. We tried to recognize small inclusions, such as skunk cabbage (Lysichiton americanum) swamps, known to be utilized by the grizzlies.

RESULTS AND DISCUSSION

Ecosystem Classification

Seven forested ecosystem associations and 19 distinct variations were described within the study area (table 2). Two additional ecosystem units important as wildlife habitat were also recognized: nonforested wetlands and avalanche tracks. These units are not, however, classified as ecosystem associations. Both include several distinct plant associations; these represent climax ecosystems in the case of the wetlands, but the avalanche tracks comprise disclimax communities maintained by repeated snow avalanche disturbances.

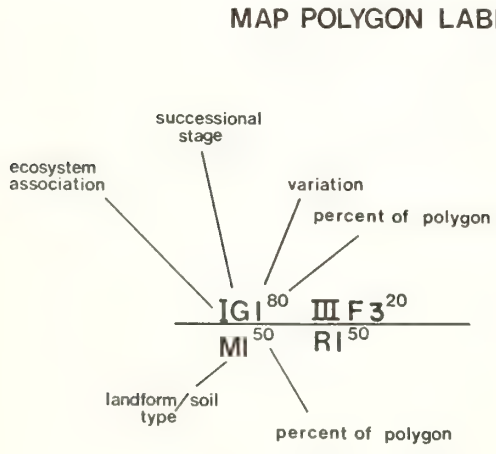


Figure 3.--Format of polygon labels for the ecosystem map.

Table 2.--Ecosystem associations of the mid-coast drier transitional coastal western hemlock zone (CWHh) in the lower Kimsquit valley

Symbol	Common name	Number of variations[1]
I	Dry Douglas-fir-shore pine-moss-lichen	4
II	Submesic hemlock-moss	1
III	Zonal hemlock-(Douglas-fir) -Vaccinium-moss	1
IV	Moist oak fern-moss	2
V	Devil's club-fern	4
VI	Flood plain spruce-devil's club	10
VII	Skunk cabbage swamp	1
VIII	Avalanche tracks (associations undefined)	None defined
IX	Nonforested freshwater wetlands (associations undefined)	None defined

[1]Variations differ in species composition from the orthic climax association and reflect different site histories or successional stages.

Most of the ecosystem associations are represented mainly by young climax to old-growth development stages. On the lower flood plain, however, fluvial disturbances as well as logging that occurred around 1918 have resulted in the dominance of pioneer seral to mature seral development stages of the flood plain spruce-devil's club and devil's club-fern associations. Herb- and shrub-dominated pioneer seral stages of zonal hemlock-Vaccinium-moss, moist oak fern (Gymnocarpium dryopteris)-moss, and devil's club-fern associations have resulted from recent logging activities along the west side of the valley, including some higher terraces of the flood plain.

We described 14 landform/soil types within the study area and have summarized these in table 3. Some associations are restricted to just one or two landform/soil types, whereas others occur on several. For example, the flood plain spruce-devil's club association occurs only on active and inactive flood plains (F1 and F2) with mainly regosolic and brunisolic soils. The zonal hemlock-Vaccinium-moss association, on the other hand, occurs on 10 of the 14 landform/soil types including morainal, colluvial, fluvial, fluvial-glacial, and glaciolacustrine landforms, where Podzols and Brunisols are the predominant soils. The ecosystem association, successional stage, and variation, together with landform/soil type, thus convey quite specific habitat information.

Table 3.--Synopsis of landform/soil types in the CWHh of the lower Kimsquit valley

Symbol	Name	Dominant soil great group[1]	Dominant humus form[2]	Particle size class[3]	Slope position and range	Associated ecosystem associations[4]	No. of plots
C1	Rubbly-bouldery colluvium	HFP, DYB, FO	HMR, LMR	CLS, SS, CL	Upper to lower slopes; 25-85 pct	II, VIII, IV, (V, III, I)	14
C2	Cobbly colluvium	HFP, FHP, SB, DYB	HMR, HUMR, MMR	CLS, SS	Upper to lower slopes; 15-75 pct	II, VIII, III, IV, V, (I)	24
C3	Fine colluvium	HFP, DYB, FHP	HMR, LMR, MLR	CL, S	Upper to lower slopes; 30-65 pct	II, IV, VIII, (III)	8
F1	Active fluvial level	R, DYB	VMR, MMR, LMR, VOR	S, FL, SS, CLS	Level; 0 pct	VI, (IX, V, VII)	39
F2	Inactive fluvial level	DYB, R, HFP	LMR, HMR, MMR	S, SS, FL	Level; 0 pct	V, VI, IV, (III, VII)	39
F3	Fluvial fans	HFP, DYB	HUMR, HMR, LMR, MMR	SS, S, FL, CLS	Lower slopes and toes; (midslopes); 0-35 pct	V, (III, IV, VI, VII)	22
G1	Fluvialglacial terraces	HFP	HUMR, HMR	CL, S	Lower slopes and level; 0-75 pct	III, (VII)	5
G2	Fluvialglacial deltas	HFP	HMR, XMR	S,SS	Upper to lower slopes and level; 0-70 pct	II, I	4
G3	Fluvialglacial deltas with cemented horizons	HFP	HUMR, HMR	CL, SS	Upper to lower slopes: 0-5 pct	III, I	2
L1	Glaciolacustrine	DYB, FHP	HMR, HUMR	C, Si	Midslope to level; 0-50 pct	III, IV, V	4
M1	Morainal	HFP, FHP, DYB	HMR, HUMR	CL, S, SS, LS	Mid to lower slopes; 5-75 pct	III, (V, II, IV, VII)	20
M2	Morainal with cemented horizons	HFP, FHP	HMR	CL, FL	Mid to lower slopes; 5-55 pct	III	3
O1	Wetland organic deposits	M, H, F	HIMR, HYMR, SML	Organic	Toeslopes; depressions; level	VII, IX	7
R1	Exposed bedrock and shallow soils over rock	FO, HFP, NS	XMR, HUMR, HMR, MMR, VMR	F, S, SS	Crests to midslopes; 20-80 pct	I, II	8

[1]Soil taxonomy follows Canada Soil Survey Committee (1978). Abbreviations: DYB, Dystric Brunisols; F, Fibrisols; FHP, Ferro-Humic Podzols; FO, Folisols; H, Humisols; HFP, Humo-Ferric Podzols; M, Mesisols; NS, non-soils; R, Regosols; SB, Sombric Brunisols.

[2]Humus form taxonomy follows Klinka and others (1981). Abbreviations: HMR, Hemimor and Hemihumimors; HIMR, Histomoder; HUMR, Humimors; HYMR, Hydromors; LMR, Leptomoders; MLR, Mullmoders; MMR, Mormoders; SML, Saprimulls; VMR, Velomoders; VOR, Velomors; XMR, Xeromors.

[3]Particle size classes follow Canadian Soil Survey Committee (1978). Abbreviations: CL, coarse loamy; CLS, coarse loamy skeletal; F, fragmental; FL, fine loamy; S, sandy; Si, silty; SS, sandy skeletal.

[4]Ecosystem associations as follows: (I) dry Douglas-fir-shore pine-Vaccinium-(salal)-moss-lichen; (II) submesic hemlock-moss; (III) zonal hemlock-(Douglas-fir)-Vaccinium moss; (IV) moist oak fern-moss; (V) devil's club-fern; (VI) flood plain spruce-devil's club; (VII) skunk cabbage swamps; (VIII) avalanche tracks; (IX) nonforested freshwater wetlands.

A table of prominence values (table 4) summarizes the climax and seral classification of the study area. This is not a complete species list but includes those species with prominence values of 50 or more in at least one unit, as well as known grizzly bear food species and some important character species of minor occurrence. Table 4 provides a quick comparison of species composition among the associations and variations. Associations are arranged from left to right along a gradient of increasing soil moisture.

Ordination of Vegetation Data

We performed several DECORANA (Hill 1979) ordinations on different subsets of the data. Ordinating vegetation data that are also being classified is useful for visually displaying the variability represented by the sample plots and illustrating relationships among ecosystem units. The most useful ordinations were obtained by subdividing the samples into forested and nonforested communities. Only the ordination of forested communities is presented here (fig. 4). Forested communities include mature seral to old-growth stages of all ecosystem associations and exclude the nonforested wetlands and avalanche tracks. The scatter diagram shows sample scores along the first two ordination axes. These two axes account for most of the variation in the data, but it is important to keep in mind that third and higher axes exist that further differentiate the samples.

We classified the releves by subjective tabular comparison before performing the ordinations; the ecosystem association and successional stage to which each sample was assigned are indicated in fig. 4. As a result of the ordinations, the classification of some releves was reevaluated and in a few cases changed. For the most part, however, the original classification remained intact, and the ordinations mainly served to illustrate the relative distinctness of, and variability within, each association.

The ordination of forested communities (fig. 4) illustrates that some associations are quite distinct, whereas others overlap with closely related associations. Samples of the driest Douglas-fir-shore pine association (I) form a tight cluster on the extreme left. The submesic hemlock-moss (II) and the zonal hemlock-Vaccinium -moss associations (III) show some overlap. Species composition is similar in these two associations (table 4), and they are distinguished more on the basis of productivity of the tree layers and relative abundance of several understory shrubs and herbs. The moist oak fern-moss (IV) and devil's club-fern (V) associations are also closely related. Again, these associations differ mainly in the relative dominance of a few species such as Oplopanax horridus and Gymnocarpium dryopteris. The alluvial spruce association (VI) is clearly separated from all other associations except V. The mature seral stands of association VI, dominated by red alder and black cottonwood,

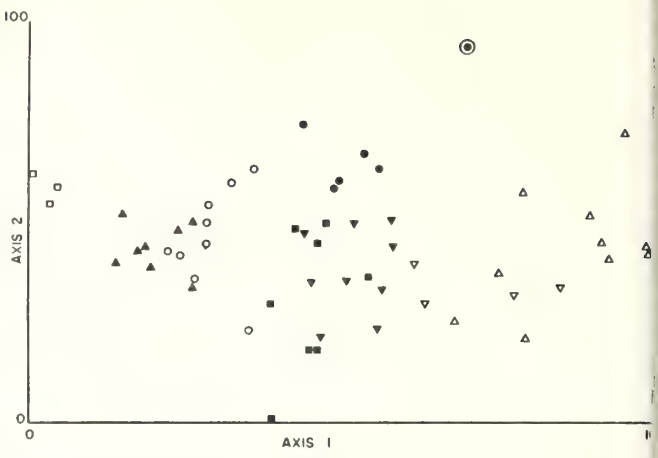


Figure 4.--DECORANA ordination of mature seral to old-growth forest communities. Association symbols: (□) dry Douglas-fir-shore-pine-moss-lichen, mature climax; (▲) submesic hemlock-moss, mature climax; (○) zonal hemlock-Vaccinium-moss, mature climax; (■) moist oak fern-moss, mature climax to old-growth; (▼) devil's club-fern, mature climax to old growth; (▽) flood-plain spruce-devil's club, mature climax to old-growth; (△) flood plain spruce-devil's club, mature seral; (●) skunk cabbage swamp, mature climax; (◉) skunk cabbage swamp, mature seral.

occur on the far right and the climax and old-growth, spruce-dominated stands ordinate adjacent to the V samples. The cluster of mature climax cedar-skunk cabbage swamp (VII) samples suggests some vegetative similarities to associations IV and V. The high cover of Lysichiton americanum, however, distinguishes VII samples from those of the other associations. The mature seral VII sample is distinctive in its domination by red alder.

The ordination of forest communities in figure 4 can be interpreted qualitatively in terms of several ecosystem characteristics. Species diversity is lowest in association I on the far left; increases to a maximum in the center (V and VII); and then declines slightly in the VI samples on the right (see table 4). As we would expect, the associations with higher species diversity are also the most variable. The highest diversity of grizzly bear food species occurs in the ecosystems on the right-hand side of the ordinations (V, VI, VII). There is a general trend of increasing forest productivity from left to right on the ordination diagram. This most likely reflects a complex gradient of increasing moisture and nutrient availability mainly along the first ordination axis.

Ecosystem Mapping

We mapped 419 polygons as pure or complex units within the 5 000 ha study area and field-checked 55 percent of these in at least one location. On the lower flood plain and on the west side of the valley where access was easiest, vegetation

Table 4.--Species prominence values[1] for successional stages and variations of ecosystem associations in the CWHh of the lower Kimsquit Valley

Strata and species	I[2]		II		III				IV			V	VI										VII		VIII		IX
	F-G[3]	A[4]	F-G	C[1]	F-H	F-H[2]	D-F[3]	C[4]	F-H	F-G[1]	C[2]	F-H	F-H	E-F[1]	E[2]	E[3]	E[4]	D[5]	D[6]	D[9]	D[10]	C[7]	B-D[8]	G	E[1]	C	B	G
TREE LAYERS:																												
Tsuga heterophylla	104		305		370	275	454		168	550		215	90	48		17	2					6		220	50			
Abies amabilis				70	147	320	83		121	18		93	35	10		T								14				
Thuja plicata			80		44		107		259	595		182	37	108		14					50	10		320	50			
Pseudotsuga menziesii	80		120		19		117		57	255		90				4					100			13				
Picea sitchensis			11				71		38	71		66	310	367		86	43			14	200	14	18	116	100	7		
Pinus contorta	143																											
Populus balsamifera ssp. trichocarpa												2	68	350	450	427	41		150	675	150							
Alnus rubra									5				19	10	50	195	550	800	100	550			53	5	200			
SHRUB LAYERS:																												
Tsuga heterophylla	275	20	103	80	160	135	30	50	57	195	19	102	23	22			22		10	28	50	8	130	200	50	4	7	
Abies amabilis	7		68		156	125	17	200	28	35	23	25	16	20			1			14		4		110	50			
Thuja plicata	55		36	10	13		25		15	105		24	1			3				35	50		55	10	50	7		
Picea sitchensis		20							5				2	8	50	36	35	5	70	85	50	19	175	10	50			
Pinus contorta	53																		5									
Populus balsamifera ssp. trichocarpa																			500				175			3		
Alnus rubra													16	4				50	450				325		100			
Acer glabrum									T	4		T							20			2		T		120		
Alnus viridis ssp. sinuata																7			100	14				2		80		
Salix sitchensis																			150	11		8	55			209	135	
Vaccinium alaskaense*	145		152	150	270	300	65		77	28	10	50	19	2		T					10	6		106	30			
Vaccinium ovalifolium*	7		80	150	170	250	6	350	30	28	127	38				2				11		8	2	132	20	2		
Menziesia ferruginea	27		67	50	100	45		40	10		8	10											4	64		2		
Vaccinium parvifolium*	63		73	150	10	4	25		15	28	4	5				2				11			2	13				
Oplopanax horridus*					T		1		30	18	33	186	350	333	990	163	272			21	100	83		100	150	198	16	
Rubus spectabilis*								20	8		136	30	123	173	600	345	483	100	10	300	50	167		32	700	113	27	71
Rubus parviflorus*				10					T	4	87	55	76	200	250	288	17		40	250	150	167	178	25		66	283	
Sambucus racemosa*				10					T		68	4	12	27	50	115	283					55				19	19	
Cornus sericea										2	65	6	14			4		50	30	75	100	173	53	54	50	71	4	
Viburnum edule*									4	4	4	12	18	10		59			20	150	200	36	4	39	100	54		
Ribes bracteosum*												T	T		50	7	35				50			T	50	24	14	
Lonicera involucrata*															50	80	16	50	50	175	50			6		T	53	
Spirea douglasii																										T	350	
HERB LAYER:																												
Cornus canadensis	2		13	80	9	85	T	50	15	42	38	11		1		3					10	33		25				
Clintonia uniflora			8	50	5	30	3	80	16	42	16	22	8	2		2						10		14		2		
Goodyera oblongifolia	T		50		6		3	5	2	23		2									5			T				
Dryopteris assimilis*			T		2	2			37		22	24	24	2	20	2	4					10		T		18	4	
Streptopus roseus			T		T	2	T		42	53	6	34	26	118	5	8	7			11	10	22		29		21	11	
Tiarella unifoliata					T		T		4		80	4	5	2		2	1			2	10	43	2	17				
Gymnocarpium dryopteris						2	3		181	45	43	161	182	58	5	3	2			23	200	17		36	5	5		
Pteridium aquilinum			1	20								T												13		42	473	
Athyrium filix-femina*			T						5	2	204	46	76	42	50	37	53	5		18	50	417		138	50	150	317	18
Circaea alpina									4		30	4	35			2	3	50				60		T		3		2
Carex sitchensis(*)																												250
Calamagrostis canadensis(*)												4								50						T	40	53
Disporum hookeri									2	55	4	13	12	11	5	9	4			4	10	4				10	41	
Polystichum munitum									1	100		6										1						
Osmorhiza spp.*										2		T		6	5	9			20	4	10			T				
Phalaris arundinacea(*)																												53
Elymus glaucus(*)																2			300	18		1	4					
Trautvetteria caroliniensis													12	161	183	300	64	103	150		60	150	2		2	T	11	18
Maianthemum dilatatum									T			3	2	65	5	23	3			35	10	1	2			5	27	
Urtica dioica													T	1		3	1									5	87	
Lysichiton americanum*												6	13									19		360	250	7		2
Equisetum arvense*												T				7	1	50		4				5		2		28
Scirpus microcarpus																		50							5			141
Aruncus dioicus													1		50			20		30			2			T	41	
Festuca subulata(*)																		5	50							3	6	
Heracleum sphondylium*																		5								4	112	

(con.)

Table 4. (Con.)

Strata and species	I[2]		II		III				IV			V	VI										VII		VIII		IX
	[3]F-G	A	F-G	C	F-H	F-H	D-F	C	F-H	F-G	C	F-H	F-H	E-F	E	E	E	D	D	D	D	C	B-D	G	E	C	B	G
		[4]1		1		2	3	4		1	2			1	2	3	4	5	6	9	10	7	8		1			
BRYOPHYTE AND LICHEN LAYER:																												
Rhytidiadelphus loreus	18		150		350	425	38	100	154	120	16	83	37	2	5			T	30	7		50	4	80		3		
Hylocomium splendens	83		400	450	180	53	37	100	59	170	10	56		2					50			1	18	89				
Rhytidiopsis robusta	20		101		57	225	53		7			13												T				
Mnium glabrescens					T				29			49	14	2		5						1		240		44	14	
Mnium insigne							1		16	18		41	84	35	5	30	27			11	50			T		19		
Rhacomitrium heterostichum		300																										
Cladonia spp.	89	170																	10				18					
Stereocaulon spp.	27	100																	20				35					
Rhacomitrium canescens	13	50																	400				325					
Pleurozium schreberi	475	30	56	150																			4	9				
Polytrichum juniperinum																			100				75					
Drepanocladus spp.																												88
Average cover (percent) of strata																												
Tree	38	0	58	0	65	60	82	0	75	83	0	73	55	70	50	63	65	85	15	78	50	5	13	50	40	6	0	5
Shrub	60	5	66	30	84	80	7	40	31	30	58	54	70	74	100	96	100	95	65	68	85	57	83	69	95	83	34	75
Herb	13	0	9	15	9	10	3	12	42	40	52	49	73	55	43	25	20	40	35	10	60	67	7	68	30	49	100	58
Bryophyte and lichen	88	50	85	65	74	80	15	20	33	40	9	42	25	14	1	6	3	5	50	2	10	11	50	72	25	12	4	25
	[5]4	1	7	1	5	2	3	1	5	2	3	9	5	3	1	4	3	1	1	2	1	3	2	5	1	4	3	2

[1]Prominence value = mean cover x $\sqrt{\text{frequency}}$. Only species with prominence values of 50 or more in at least one unit are included in the table (except for a few grizzly bear food species). Known grizzly bear food species are marked with an asterisk [*]. Uncertain food species are marked with a parenthetical asterisk [(*)].

[2]Ecosystem associations as follows: (I) dry Douglas-fir-shore pine-moss-lichen; (II) submesic hemlock-moss; (III) zonal hemlock-(Douglas-fir)-Vaccinium moss; (IV) moist oak fern-moss; (V) devil's club-fern; (VI) flood plain spruce-devil's club; (VII) skunk cabbage swamps; (VIII) avalanche tracks; (IX) nonforested freshwater wetlands.

[3]Successional stages as follows: (A) nonvegetated or bryoid; (B) herb pioneer seral; (C) shrub - seedling pioneer seral; (D) pole - sapling; (E) mature seral; (F) young climax; (G) mature climax; (H) old growth.

[4]Variations of ecosystem associations as follows: I(1), Rhacomitrium-lichen; II(1), Vaccinium-bunchberry; III(2), amabilis fir-Rhytidiopsis; III(3), nudum; III(4), Vaccinium-queen's cup; IV(1), sword fern; IV(2), Rubus-oak fern; VI(1), cottonwood-spruce-salmonberry-devil's club; VI(2), cottonwood-devil's club; VI(3), cottonwood-alder-salmonberry-devil's club; VI(4), alder-salmonberry-elderberry; VI(5), alder-salmonberry; VI(6), alder-grass; VI(7), salmonberry-lady fern; VI(8), alder-willow-fireweed-Rhacomitrium riverbar complex; VI(9), cottonwood-alder-twinberry; VI(10), spruce-cottonwood-thimbleberry; VII(1), alder-salmonberry.

[5]Number of releves (total = 84).

patterns most complex, and grizzly bear activity the highest, we field-checked 80 percent of the polygons.

Area summaries by ecosystem unit were produced for the portion of the map that was digitized and entered onto the CAPAMP system (90 percent of the 5 000 ha map area; 351 polygons). Figure 5 summarizes map area percentages for each association. The climatic climax or zonal association (III) covers the largest area, followed by the submesic hemlock-moss association (II). Together these two associations comprise over 50 percent of the digitized map.

The flood plain spruce-devil's club (VI) and the devil's club-fern (V) associations cover significant portions of the map area (17 and 11 percent, respectively) and show abundant evidence of grizzly activity (see Hamilton and Archibald this volume). Skunk cabbage swamps (VII), avalanche tracks (VIII) and nonforested wetlands (IX) cover less than 3 percent of this lower elevation map area. Although of minor extent, these ecosystems provide important grizzly bear habitat.

Classification and Mapping of Flood Plain Communities

A discussion of the flood plain spruce-devil's club ecosystem association and its 10 seral variations will serve as a working example of our approach to the classification and mapping of seral ecosystems. Flood plain ecosystems are among the most important grizzly bear habitats in the study area, partly because of their proximity to the salmon spawning channels of the Kimsquit River but also because of the diversity of grizzly food plants that grow in flood plain communities. The complex mosaic of seral stages belonging to the flood plain spruce-devil's club association also presented the greatest challenge for classification and mapping.

Table 4 summarizes the vegetative features of the flood plain spruce-devil's club climax association and the 10 seral variations that we recognized. Table 5 summarizes selected site factors. Figure 6 illustrates the relative extent of each of the flood plain spruce variations for the digitized portion of the map.

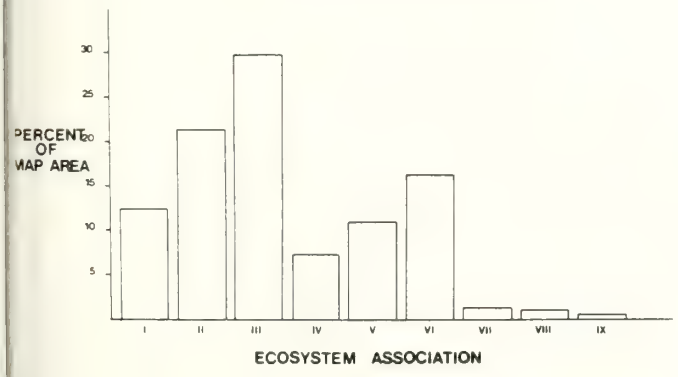


Figure 5.--Percentage of digitized map area covered by each ecosystem association. Association symbols: (I) dry Douglas-fir-shore pine-moss-lichen; (II) submesic hemlock-moss; (III) zonal hemlock-Vaccinium-moss; (IV) moist oak fern-moss; (V) devil's club-fern; (VI) flood plain spruce-devil's club; (VII) skunk cabbage swamp; (VIII) avalanche tracks; (IX) nonforested freshwater wetlands.

Pioneer seral development stages on the flood plain are represented by two variations: the salmonberry (Rubus spectabilis)-lady fern (Athyrium filix-femina) variation (7) and the alder-willow (Salix spp.)-fireweed (Epilobium spp.)-Rhacomitrium variation (8). These two variations exemplify early succession on fluvial substrates of contrasting textures and moisture/nutrient regimes (table 5). The alder-willow-fireweed-Rhacomitrium variation develops where severe and repeated disturbance by fluvial scouring and deposition creates freshly exposed, coarse-textured, and usually dry substrates. It is thus widespread along the active portions of the flood plain. The salmonberry-lady fern variation apparently results from less severe disturbances such as windthrow or logging that remove the tree canopy but enhance the growth of invader or residual understory species. This variation comprised less than 1 percent of the area mapped as the flood plain spruce-devil's club association.

Many alluvial soils have fine-loamy surface horizons overlying gravelly horizons at depth. On parts of the lower Kimsquit flood plain, recent, severe logging disturbance has removed or disturbed this fine-textured surface horizon, reducing site productivity to the extent that secondary succession is similar to that

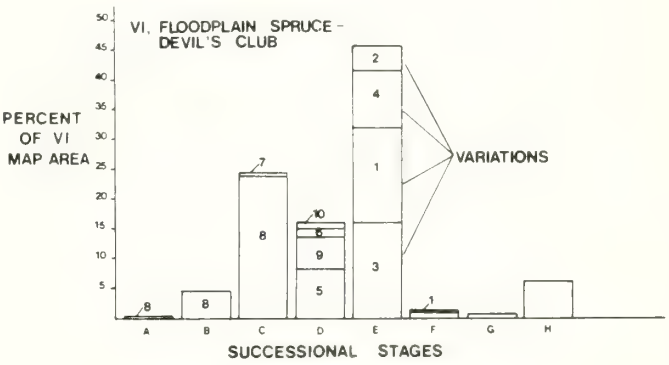


Figure 6.--Percentage of flood plain-spruce devil's club map area covered by each successional stage and variation. Successional stage designations: (A) nonvegetated or bryoid; (B) herb pioneer seral; (C) shrub-seedling pioneer seral; (D) pole-sapling; (E) mature seral; (F) young climax; (G) mature climax; (H) old-growth. Variation designations: (1) cottonwood-spruce-salmonberry-devil's club; (2) cottonwood-devil's club; (3) cottonwood-alder-salmonberry-devil's club; (4) alder-salmonberry-elderberry; (5) alder-salmonberry; (6) alder-grass; (7) salmonberry-lady fern; (8) alder-willow-fireweed-Rhacomitrium; (9) cottonwood-alder-twinberry; (10) spruce-cottonwood-thimbleberry. Bars without numbers represent orthic climax vegetation for the association.

Table 5.--Synopsis of the flood plain spruce-devil's club ecosystem association and its seral variations in the CWHh of the lower Kimsquit valley

Ecosystem variation No.	Common name	Successional stage	Age (years)	Ecological moisture regime[1]	Soil subgroup[2]	Humus form[3]	Particle size class[4]	No. of plots
VI	Orthic vegetation	Young climax-old growth (F-H)	85-200+	Mesic-subhygric	GL.DYB, O.DYB, O.R, GLCU.R	MMR	S, SS, CL	8
VI(1)	Cottonwood-spruce-salmonberry-devil's club	Mature seral-young climax (E-F)	40- 88	Subhygric	O.DYB, GL.DYB, GL.R, GLCU.R	LMR, MMR VML, VMR	S, SS, CL, FL	8
VI(2)	Cottonwood-devil's club	Mature seral (E)	52- 65	Subhygric	O.SB	MLR	CL	1
VI(3)	Cottonwood-alder-salmonberry-devil's club	Mature seral (E)	45- 67	Mesic-subhygric	O.R, CU.R, GL.R	LMR, VMR MMR	S, SS, CL	8
VI(4)	Alder-salmonberry-elderberry	Mature seral (E)	30- 60	Subhygric	GL.DYB, O.DYB O.R, CU.R	VMR, LMR VOR, MMR	S, SS, CL	14
VI(5)	Alder-salmonberry	Pole-sapling (D)	8- 10	Subhygric	GLCU.R	VMR, RML	FL, CL	3
VI(6)	Alder-grass	Pole-sapling (D)	5- 25	Submesic	O.R, O.SB	VOR, RML	S, SS, CLS	3
VI(7)	Salmonberry-lady fern	Shrub-seedling pioneer seral (C)	5- 15	Subhygric	GL.EB, GL.HFP	LMR	S, FL	1
VI(8)	Alder-willow-fireweed-Rhacomitrium river bar complex	Herb/shrub seedling pioneer seral and pole-sapling (A-C)	20- 40	Submesic-mesic	O.R	XMR, VMR	SS	2
VI(9)	Cottonwood-alder-twinberry	Pole-sapling (D)	20- 35	Mesic-subhygric	O.R, CU.R, GLCU.R	VMR	S	4
VI(10)	Spruce-cottonwood-thimbleberry	Pole-sapling -mature seral (D-E)	30- 50	Mesic	O.R	LMR	S	1

[1]Ecological moisture and nutrient regimes are a subjective assessment of relative moisture and nutrient availability (Pojar 1983).
[2]Soil taxonomy follows Canada Soil Survey Committee (1978). Abbreviations: CU.R, Cumulic Regosols; GLCU.R, Gleyed Cumulic Regosols; GL.DYB, Gleyed Dystric Brunisols; GL.EB, Gleyed Eutric Brunisols; GL.HFP, Gleyed Humo-Ferric Podzols; GL.R, Gleyed Regosols; O.DYB, Orthic Dystric Brunisols; O.R, Orthic Regosols; O.SB, Orthic Sombric Brunisols.
[3]Humus form taxonomy after Klinka and others (1981). Abbreviations: HMR, Hemimors and Hemihumimors; LMR, Leptomoders; MLR, Mullmoders; MMR, Mormoders; RML, Rhizomulls; VMR, Velomoders; VOR, Velomors; XMR, Xeromors.
[4]Particle size classes follow Canada Soil Survey Committee (1978). Abbreviations: CL, coarse-loamy; CLS, coarse-loamy skeletal; FL, fine-loamy; S, sandy; SS, sandy-skeletal.

occurring on the coarse-textured gravel bars. The nature and severity of disturbance thus has a large bearing on secondary succession.

We described four pole-sapling variations of the flood plain spruce association. These are: alder-salmonberry (5), alder-grass (6), cottonwood-alder-twinberry (Lonicera involucrata) (9), and spruce-cottonwood-thimbleberry (Rubus parviflorus) (10). The alder-salmonberry variation has been mapped as a variation of both the flood plain spruce and devil's club-fern associations. It is the wettest young-seral variation and represents 8- to 10-year-old, dense alder stands on fine-loamy to loamy Gleyed Cumulic Regosols with Moder and Mull humus forms. This community typically occurs adjacent to meandering back channels and as a result may be subject to frequent flooding.

The alder-grass variation is relatively uncommon but occurs on some gravelly, often compacted, alluvial deposits. The origin of this community is unclear, but it was sometimes found on what appeared to be old skid trails and it may reflect soil disturbance and compaction resulting from logging in the early 1900's. This variation may also represent further successional development from the alder-willow-fireweed-Rhacomitrium variation.

Both the cottonwood-alder-twinberry variation and the spruce-cottonwood-thimbleberry variation are found on Regosols developed in sandy fluvial materials. These variations occur predominantly upstream of the early logging, and they probably originated from more recent fluvial disturbances that left behind fine-textured materials (sands rather than gravels). Spruce-cottonwood-thimbleberry is the drier of these two variations and is dominated by conifers (Sitka spruce, Douglas-fir, and redcedar), whereas the more widespread cottonwood-thimbleberry variation is mainly deciduous, with conifers in the understory. This may partially reflect the differences in age between these two variations (table 5), but other factors such as seed sources, soil moisture, and site history have undoubtedly influenced species composition as well.

The four mature seral variations of the flood plain spruce association are: cottonwood-spruce-salmonberry-devil's club (1), cottonwood-devil's club (2), cottonwood-alder-salmonberry-devil's club (3), and alder-salmonberry-elderberry (Sambucus racemosa) (4). Two of these (1 and 4) have also been mapped as seral variations of the devil's club - fern association. These four mature seral variations make up almost 50 percent of the flood plain spruce-devil's club map area (fig. 6) and probably represent stands established after the 1918 logging.

A comparison of these four variations in table 5 reveals only minor differences in moisture/nutrient regimes, soil subgroups, humus forms, and soil particle size. Variation in species composition must therefore be explained by other factors such as age of the stand, disturbance regimes, seed sources, species composition before disturbance, and chance. Unfortunately, we lack information on all of these factors except age.

Cottonwood-spruce-salmonberry-devil's club is the oldest of the four variations (40 to 88 years). Some examples of this variation were classified as young climax because they contained significant amounts of spruce and other conifers in both the overstory and understory.

The data illustrate that the relative amounts of Alnus rubra and Populus trichocarpa in seral communities are at least partially related to maturity of the stand. Most seral communities contain both species but the youngest examples of mature seral variations are dominated by Alnus (4) and the oldest by Populus (1 and 2). These two species appear to have similar ecological requirements and tolerences in flood plain habitats, and both are prolific seed producers (Fowells 1965). Populus, however, reproduces vegetatively (by suckers as well as sprouts) more effectively than Alnus (which does not produce suckers). In addition, Populus is a longer living and taller species. Although the proportions of these two species in early and midsuccessional stages may be determined by site history and chance, and both species are characterized by high initial growth rates, Populus is able to maintain height growth longer and eventually dominate these seral stands as they approach maturity.

Only localized areas of climax and old-growth alluvial forests remain in the lower Kimsquit valley (fig. 6). These impressive forests are dominated by Sitka spruce and usually contain other coniferous species as well as scattered mature individuals of black cottonwood.

CONCLUSIONS

We developed an approach to ecosystem classification and mapping that links structural development stages and present species composition to a climax-based biogeoclimatic classification. The three levels of ecosystem generalization (the ecosystem association, successional stage, and variation) together with the landform/soil units form a useful framework for evaluating coastal grizzly bear habitat (Hamilton and Archibald this volume). Derivative maps for specific habitat interpretations can be produced using one or more of these classification levels depending on the required detail. Habitat ratings for some activities such as feeding, may require specific information on species composition; this is provided at the level of ecosystem variation. The successional stage category, on the other hand, provides sufficient information for other habitat interpretations such as cover. For broad-scale habitat evaluations of entire watersheds, a map of associations or groups of related associations and seral stages may be all that is required. A computer-assisted mapping system facilitates the rapid production of such derivative maps.

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GRIZZLY BEAR HABITAT IN THE KIMSQUIT RIVER VALLEY, COASTAL BRITISH COLUMBIA: EVALUATION

Anthony N. Hamilton and W. Ralph Archibald

ABSTRACT: A grizzly bear (Ursus arctos) habitat evaluation procedure was developed as part of an interagency research project designed to assess the impacts of logging on grizzlies in coastal British Columbia. Discrete habitat units in the Kimsquit River valley were investigated to determine how they meet various bear requirements (feeding, bedding, marking, traveling, denning) on a seasonal, annual, and between-year basis. Specifics of the evaluation procedure, which is based on a mobile ground telemetry system and a detailed grizzly activity site investigation process, are discussed. Preliminary results of the evaluation procedure for a specific activity--feeding--are presented.

INTRODUCTION

The coastal valleys of mainland British Columbia support some of the highest grizzly bear densities in the province. These valleys also produce some of the most valuable timber in B.C. Logging in these valleys coincides with declines in grizzly numbers (Archibald 1983), but it is unknown whether the declines are due to habitat change, excessive hunting during and post logging, or both. The provincial Ministry of Environment, Wildlife Branch, feels that grizzly numbers must be maintained in coastal forests to achieve management objectives. To do so the historical pattern of logging coastal forests with corresponding declines in grizzly populations must be broken.

In April 1982, a research project was begun to provide the information necessary to address the long-term welfare of coastal grizzlies in areas being logged or scheduled for logging. This project is funded and administered cooperatively by the B.C. Ministries of Environment and Forests. Additional funding has been provided by the University of British Columbia and the Canadian Wildlife Federation.

One of the primary objectives of the research is to determine the seasonal habitat requirements of coastal grizzlies. We developed a three-part strategy of habitat classification, mapping, and evaluation to meet this objective. Banner and others (this volume) describe the procedures used to classify and map grizzly bear habitat in the study area. Our paper summarizes the methods we used to evaluate how grizzlies used discrete habitat units to meet their life requisites (feeding, bedding, marking, traveling, and denning) on seasonal, annual, and year-to-year bases. We present preliminary results of the evaluation procedure for feeding to illustrate the results of this strategy thus far.

Grizzly bears in coastal systems differ from most interior and northern populations of grizzlies in that they have access to salmon. Salmon are a readily available, abundant source of meat protein and play a major role in the feeding habits, movement, behavior, and activity patterns of coastal grizzlies. The impacts of salmon are bein documented and will be presented in a future paper

STUDY AREA

The 50,000-ha study area is the Kimsquit River valley, located 500 km northwest of Vancouver (fig. 1). The topography is rugged, with steep mountains rising abruptly from sea level to over 2 000 m. Hamilton (1984) describes the study area in detail. Habitat classification and mapping of the study area have been completed at a scale of 1:20,000, using the biogeoclimatic system developed by Krajina (1970) (Banner 1985; Clement 1984a,b).

The Kimsquit River goes through a narrow canyon approximately 18 km from the estuary. This canyon conveniently divides the watershed into intensive and extensive areas for study. The intensive area is below the canyon, and ground access is provided by 25 km of logging roads and the navigable river. The extensive area is inaccessible except by aircraft or walking. In this paper, we consider only that portion of the intensive area mapped by Banner and others (this volume).

METHODS

To evaluate how grizzlies used habitat units, we used a data collection strategy that involved capturing and radio-collaring a sample of grizzlie resident to the study area, determining their locations daily, and then conducting site investigations at these locations.

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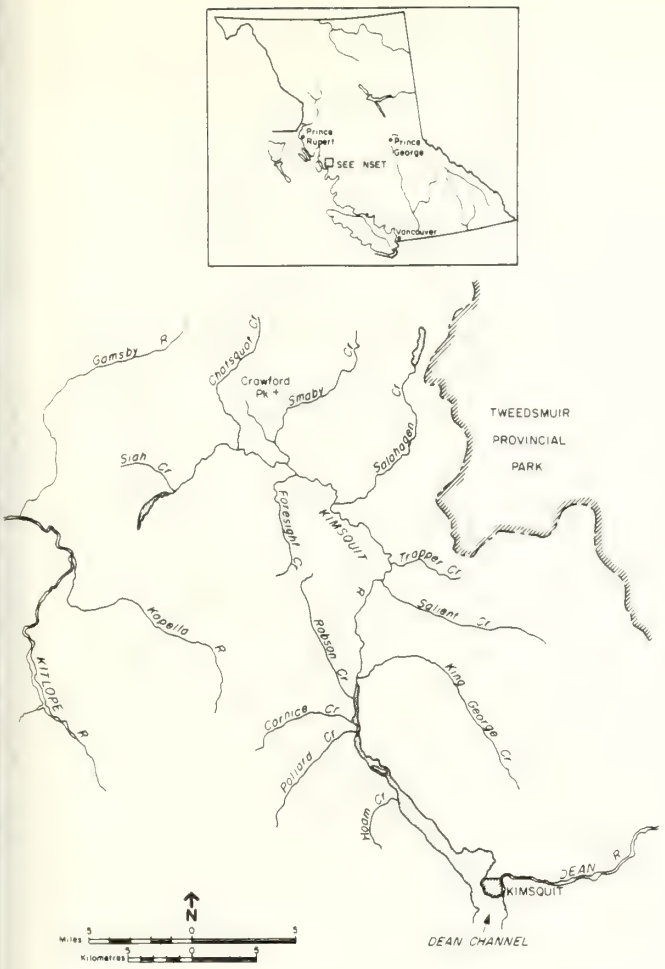


Figure 1.--Location of the Kimsquit River Valley grizzly bear habitat study area.

Capture

We captured grizzlies with Aldrich foot snares in baited cubby sets and trail sets in areas of easy access from the road or river. Transmitter beacons were attached to each snare to permit monitoring of the trapline from a distance (Nolan and others 1984). This procedure improved trapping efficiency and safety for the capture team.

We immobilized captured bears with M99 (etorphine hydorchloride). Immobilized bears were handled using techniques similar to those reported by other researchers (Russell and others 1979; Glen and Miller 1980), and were equipped with radio collars (Telonics, Mesa, AZ).

Radio relocations

Because the success of the data collection strategy depended on reliable locations of bears, we developed a telemetry system that met the following criteria:

1. Allowed for the rapid collection of consecutive bearings.
2. Allowed for field determination of location precision.
3. Protected the receiving equipment from the inclement weather typical of coastal forests.

Twenty-five kilometers of logging roads made possible the development of a vehicle-mounted monitoring system. This system consisted of an elevating antenna mast with a four-element yagi antenna, a dash-mounted magneysn compass, a scanning receiver, and a portable, battery-powered computer with approximately 10K RAM memory (Sharp PC 1500).

The elevating antenna mast was mounted through the cab of the project vehicle so the driver could raise and lower the antenna without leaving his or her seat, and, so the antenna could be manipulated while driving the vehicle. A combination of rough logging roads and heavy roadside vegetation limited the maximum height of the antenna to 4.5 m from the ground. A compass rose attached to the bottom of the mast was keyed to the mast so that when the rose was set to zero, the antenna pointed forward.

A magneysn remote compass mounted in the vehicle permitted rapid determination of the vehicle direction. This compass consisted of a remote sensor and an indicator calibrated in degrees. We installed the sensor in a shock-resistant aluminum box and mounted it on the fiberglass canopy in the rear of the vehicle to minimize unwanted magnetic influences.

We used an error polygon (Heezen and Tester 1967; Springer 1979) program developed in BASIC by Page (1983), to determine the precision of the relocation while in the field. This short program could receive up to five bearings and determine that at least one bearing was inaccurate. The operator had to determine which bearing was to be eliminated. Output from this program included all input data (station number and bearing) plus the Universal Transverse Mercator (U.T.M.) coordinates of the vertices of the error polygon, the U.T.M. coordinates of the centroid, the area of the polygon in hectares (a smaller polygon implying a more precise location), and a plot of the polygon's shape.

The steps in locating a collared grizzly were as follows. The investigator drove to the station closest to where the last bearing was recorded, raised the antenna, locked it into position, and scanned through 360°. If no signal was heard, or if the signal was too weak for a reliable bearing, the investigator partially lowered the antenna and drove toward the next closest station for the last known location, monitoring along the way.

When a signal was received, the operator determined the bearing by the strongest signal method, repeating this process several times to test the precision of the measure, and then entering bearing direction, magnesyn compass reading, and monitoring station number into the computer. The U.T.M. coordinates of the station were extracted from computer memory. After recording three to five positions, we ran the program, taking consecutive bearings and entering them until the size of the error polygon was as small as possible.

Site Investigations

We attempted to identify and evaluate habitat characteristics which are important in determining movements between and use of specific habitat units by conducting site investigations in areas of recent grizzly activity. The U.T.M. coordinates of radio-located bears were transferred daily to an air photo mosaic; locations having an uncertainty area of less than 1 ha were selected for investigation the following day. We did not attempt to visit the site if the bear remained in the same area. We used colour air photographs (1:20,000) to navigate to the centroid of the location polygon, and then searched the area for evidence of recent grizzly activity. When we encountered bear activity, the exact site location, confirmation of grizzly activity, and date of use were required to complete a site investigation form. Where possible, activities were assigned to individual grizzlies. Ground follow-up of visual observations, periodic visitation to areas of traditional grizzly use, and chance encounters with grizzly sign also provided records of activity.

Information collected during site investigations included the ecosystem unit as defined by Banner and others (this volume) and which grizzly activities had occurred at the site (feeding, bedding, tree marking, trail marking, traveling and other). It was not uncommon to have more than one activity per site. We also recorded a number of site characteristics, which were selected on the basis of their suspected biological relevance to bears and which had to be measurable to a desired level of precision. A sample site investigation form is presented in Appendix A.

Seasons of grizzly activity were based on information collected during site investigations. Eight annual grizzly seasons were defined on the basis of plant phenology and the availability of preferred food. Following is a brief description of each season.

Season number	Start	Definition
1	Early April	Emergence to valley floor leaf flush
2	Mid-April	Leaf flush to avalanche chute green up
3	Late May	Avalanche chute green up to berry production
4	Mid-June	Berry production, no salmon
5	Late July	Berries and salmon
6	Late August	Salmon, no berries
7	Mid-October	Post-salmon
8	Early November	Denning

The dates listed above are approximations only because of the between-year variation in season commencement. For example, in 1982, season 4 began on July 1, whereas in 1983 it began on June 16.

Feeding Evaluation

Diet analysis.--In 1982, bear scats were collected as encountered. In 1983 and 1984 only known-bear, known-date scats were collected. Samples were air dried in the field and stored in paper bags until analysis. In the lab, samples were resaturated in water and washed through two screens of mesh sizes 4 mm and 1 mm. Five subsamples were selected randomly for examination under a stereo microscope (2X and 4X). Scat material was identified to species when possible, but grasses and sedges were classified only to family. Percent occurrence by volume was recorded in the following classes (Servheen 1979): 0-1, 1-5, 5-25, 25-50, 50-75, 75-95, 95-100 and averaged for the five subsamples.

Site analysis.--Where we could verify feeding activity, we collected specific site data. We identified food species, listed them in order of volume consumed, and classified them by phenologic stage. For fruit-producing shrubs and salmon, we also determined approximate abundance.

In 1984, we collected representative food samples for analyses of crude protein, acid detergent fibe and energy. At verified feeding sites, three type of samples were collected: remains of what the bea had consumed, a mimic (or imitation) of what the bear had selected, and a mimic collected up to a month later. These analyses will be compared to the analysis of food plants collected once per season at permanent plots. Hypotheses regarding the influence of food quality on seasonal habitat and within site food selection are being tested.

Computer mapping.--Two 1:20,000 map sheets coverin the majority of the study area and all of the area mapped by Banner and others (this volume) were digitized for the computer-aided planning assessme and map production (CAPAMP) system developed by th British Columbia Ministry of Environment. CAPAMP will rapidly measure availability of all mapped units and produce interpretive maps that can be used to direct further research or highlight areas of management concern (Archibald and others 1985).

RESULTS

Three seasons of field work have been completed (1982-84). Seasons generally proceeded from early April through mid-October, except when a labor dispute closed the camp from July 29 through August 21, 1982, and when field work terminated on September 9, 1982.

Capture

Twelve grizzlies have been captured in the intensive study area, four of which are known to have died subsequently. One adult male was shot by a hunter, a subadult male was shot as a problem bear a subadult female is believed to have died of natural causes, and an adult male died as a result of immobilization.

We have observed additional unmarked grizzlies within the intensive study area. The area is bein trapped again in the spring of 1985 in an attempt to replace radio collars and to capture all unmarked resident grizzlies.

Radio relocations

We have collected the majority of data in the intensive study area from two resident, adult female grizzlies, numbered 08 and 25. To date we have recorded 362 ground radio relocations for female 08 and 344 relocations for female 25. These radio relocations plus a few visual observations have led to 106 verified ground locations for female 08 and 126 verified ground locations for female 25. We verified grizzly bear activity at approximately 35 percent of ground telemetry locations.

We tested the accuracy of the telemetry system by placing a radio collar at known locations throughout the study area and then plotting their locations using the standard telemetry methodology. Preliminary analysis of these data reveals that caution must be exercised when determining habitat use strictly from unverified ground telemetry data. We have analyzed 12 of 52 tests to date and only in one case was the test collar within the error polygon. The average distance from the centroid of the polygon to the test collar was 150 m.

Site investigations

To date, we have completed 406 site investigations on identified and unidentified grizzlies and have 786 records of grizzly activity.

Diet analysis.--We observed an attempted kill of an ungulate only once, on April 29, 1984 when two sibling male grizzlies chased an adult moose in a cutover. We do not know whether they were successful. We found one bear-scavenged moose carcass in 1982 and collected several grizzly scats containing moose calf hair in early July 1983. We have recorded evidence of 29 foods for Kimsquit grizzly bears, based on scat analyses and investigations of feeding sites (table 1). Diet consists primarily of plant material, including shoots, roots, and berries, but also includes salmon. Six food items appear to form the bulk of the diet (table 2).

Table 1.--Verified grizzly foods--Kimsquit Valley[1]

Latin name	Common name	Parts consumed
Plants		
Angelica genuflexa	White angelica	Roots, stems, and leaves
Athyrium felix-femina	Ladyfern	Pinnae
Carex sitchensis	Sitka sedge	Blades
Cicuta douglasii	Water hemlock	Stems and leaves
Cornus sericea	Red-osier dogwood	Berries
Equisetum spp.	Horsetail	All?
Heracleum sphondylium	Cow-parsnip	All
Lonicera involucrata	Black twinberry	Berries
Lupinus nootkatensis	Nootka lupine	Roots
Lysichiton americanum	Skunk cabbage	Roots (some leaves)
Oplopanax horridus	Devil's club	Leaf stems and berries
Osmohiza chilensis	Mountain sweet-cicely	Roots
Poaceae	Grasses	Blades
Ribes bracteosum	Stink currant	Berries
Rubus idaeus	Red raspberry	Berries
Rubus spectabilis	Salmonberry	Shoots, leaves, and berries
Sambucus racemosa	Red-elderberry	Berries
Scirpus microcarpus	Smallfruited bulrush	Blades
Carex spp.	Sedges	Blades
Streptopus roseus	Rosy twisted Stalk	Berries
Vaccinium spp.	Blue and red huckleberries	Berries
Veratrum viride	Green false hellebore	Stems
Viburnum edule	Highbush cranberry	Berries
Insects		
Cedoptera spp.	Beetle	Larvae
Bombus spp.	Honeybee	Larvae
Fish		
Oncorhynchus gorbuscha	Pink salmon	All
Oncorhynchus keta	Chum salmon	All
Oncorhynchus nerka	Sockeye salmon	All
Mammals		
Alces alces	Moose	Flesh

[1] Plant nomenclature follows Talor and MacBryde (1977) for both common and scientific names.

Table 2.--Most common food items at feeding sites of bear numbers 08 and 25

Food	N	Percent
Scirpus microcarpus	13	7.6
Lysichiton americanum	21	12.4
Oplopanax horridus	24	14.1
Rubus spectabilis	11	6.5
Sambucus racemosa	18	10.6
Salmon (fresh)	25	14.7
Salmon (rotten)	10	5.9
Other	48	28.2
	[1]170	

[1] At 117 different feeding sites.

For some food species, particularly those that are grazed (for example, sedges, grasses, horsetails, ladyfern, but also Vaccinium spp.), verification of use was often difficult because feeding sign was hard to find. Thus, these species may be underrepresented in the tables. When completed, scat analyses will help correct this bias. Either method alone is inadequate to describe diet reliably.

Habitat unit evaluation for feeding.--We have recorded 112 records of feeding activity for bears 08 and 25, in 25 different seral variations of the ecosystem associations described by Banner and others (this volume). Sixty-four percent (72 of 112) of the records of feeding have been recorded in the Floodplain spruce (Picea sitchensi devil's club (Oplopanax horidum) ecosystem association and its seral variations (table 3).

Table 3.--Frequency of feeding in the variations of the floodplain spruce ecosystem association by bear numbers 08 and 25

Symbol[1]	Name Ecosystem variation	Successional stage	Frequency
VI	Orthic vegetation	Young climax-old growth (F-H)	8
VI(1)	Cottonwood-spruce-salmonberry-devil's club	Mature seral-young climax (E-F)	10
VI(2)	Cottonwood-devil's club	Mature seral (E)	7
VI(3)	Cottonwood-alder-salmonberry-devil's club	Mature seral (E)	6
VI(4)	Alder-salmonberry-elderberry	Mature seral (E)	11
VI(5)	Alder-salmonberry	Pole-sapling (D)	15
VI(6)	Alder-grass	Pole-sapling (D)	2
VI(7)	Salmonberry-ladyfern	Shrub-seedling pioneer seral	0
VI(8)	Alder-willow-fireweed-Rhacomitrium-river bar complex	Herb/shrub seeding pioneer (A-C) seral	9
VI(9)	Cottonwood-alder-twinberry	Pole sampling (D)	4
VI(10)	Spruce-cottonwood-thimbleberry	Pole sampling-mature seral (D-E)	0

[1] Explanation of ecosystem variation symbols can be found in Banner and others (this volume).

Apparently, grizzlies select this ecosystem association for feeding partly because of its proximity to salmon.

DISCUSSION

The relatively low conversion rate of radio relocations to site investigations is explained by two factors: ground telemetry in the study area being limited by thick vegetation, rock cliffs, frequent wind and rain, and variable microtopography across the floodplain; and, the rigorous verification criteria used to select sites. Bear activity was actually encountered near relocation sites approximately 50 percent of the time but resulted in only a 35 percent conversion rate because of a high density of black bears in the valley and the great amount of different age bear sign we encountered on the floodplain.

Regardless of the low conversion rates, our telemetry system has proved adequate for our purposes. Repeated testing of the accuracy and precision of the ground telemetry system determined the extent of relocation error. As a result, we increased the search area around a recent telemetry relocation. Better ground telemetry would have reduced the searching time for grizzly use sites, increased the number of site investigations, and prevented potential bias in habitat unit evaluation resulting from non-uniform ground telemetry coverage. Aerial relocation data, ground telemetry testing, and rigorous analysis of movement data (by taking into account the distribution of relocations over time) will help to eliminate this bias.

The telemetry system did fulfill two of the original three criteria. That is, it permitted rapid collection of consecutive bearings and protected the equipment from inclement weather. In addition, this system was excellent for telemetry at night.

The site investigation procedure has proven to be time consuming and labor intensive. Initial discussions with statisticians led us to believe that the data we were collecting could be used to build a quantitative model of habitat selection; however, further discussions and attempts at data analysis have resulted in our abandoning this work. Major problems with the data-set are that it contains a combination of continuous and categorical variables, and that consecutive bear locations are not independent of one another.

The site investigation procedure has proven successful in spite of these shortcomings. It has allowed us to assign grizzly activities (not just locations) to specific habitat units--these data are essential to the habitat unit evaluation procedure. Simple summary statistics can be run on all continuous variables, and frequency summaries and contingency testing of categorical variables can help to identify patterns and allow testing for significant differences between individual bears, activities, and seasons. Such procedures, although not statistically eloquent, do provide information useful for management.

We suggest considering numerous factors when evaluating grizzly habitat units in terms of their value to grizzlies on a seasonal and annual basis. These factors include the following:

1. The area coverage and distribution of the unit (spatial availability).
2. When and how long the unit's features remain attractive to bears and their annual variability (temporal availability).
3. The number, spatial and temporal availability of alternate, equivalent-value habitat units during the period of bear use for a particular unit.
4. The details of bear use of the unit: the timing, extent, life requisite being satisfied, and the number of bears using the unit are required information (relocation biases and the distribution of bear locations over time must be accounted for to provide truly representative information about the nature, timing, and extent of use).
5. The amount of human disturbance (for example, noise or physical presence of people or vehicles) and its influence on bear use of the unit.

The procedure outlined to evaluate the floodplain spruce ecosystem association for feeding will be expanded to include the above factors in future reports. In this way, all habitat units will be ranked in terms of their value to grizzlies in the intensive study area on a seasonal and annual basis.

Once we know the comparative value of habitat units for all activities and all seasons, the CAPAMP system can be used to generate interpretive maps useful to management. For example, this system could be used to display the distribution of seasonally important habitat units for grizzlies.

In conclusion, the system that we are using to evaluate the habitat units mapped by Banner and others (this volume) is still evolving. We plan to field test unit evaluation for a number of other watersheds to determine whether we can extrapolate our results over the coast. We are confident that the process outlined in this paper is the correct strategy for our study area, and that the results of our research will allow us to achieve project objectives.

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FISH & WILDLIFE BRANCH
RESEARCH SECTION

SITE INVESTIGATION FORM

FORM #

SITE CHARACTERISTICS

SITE #

DATE D D M M Y Y

SURVEYORS

X COORD

Y COORD

PLOT SIZE m

ELEVATION m

SLOPE

ASPECT

HABITAT CHARACTERISTICS

TYPE

POLYGON

STRATA %
TREE B1 B2 C D

COVER VALUE
N E S W

TYPE
1 Shrubs
2 Debris
3 Topography
4 Trees
N E S W

TRAFFICABILITY (circle 1 max)
1 Unrestricted
2 Slight
3 Restricted
4 Very
5 Extreme

SOIL TYPE

MOISTURE

NUTRIENT

HUMUS

SURFACE TEX

SURFACE SUBSTRATE %
LITTER HUMUS DECAY WOOD BEDROCK ROCKS MINERAL SOIL H2O

FLOODING (circle 1 max)
1 Now
2 1 Month
3 This Year
4 Non-Active

ACTIVITY CHARACTERISTICS

ACTIVITY (circle 6 max)
1 Bed
2 Feed
3 Mark Tree
4 Mark Tra
5 Travel
6 Other
SPECIFY
Primary Activity

SEASON (circle 1 max)
1 Leaf Flush
2 Nuts/Berry Drop
3 Berry Production
4 Berry In Salmon
5 Berry & Salmon
6 Salmon
7 Post Salmon

WX AT USE (circle 1 max)
1 Unknown
2 Rain
3 Intermittent Rain
4 Overcast
5 Cloudy
6 Few Clouds
7 Clear
8 Other
SPECIFY

USE RECORDED DATE
D D M M Y Y

SIGN AGE

BEAR #

RELOC SHEET #

TELEMETRY RELIABILITY
(circle 1 max)
1 Positive
2 Probable
3 Possible
4 Doubtful

VERIFICATION
(circle 1 max)
1 Hair
2 Tracks
3 Teeth
4 Scats
5 Age
6 Other
7 Distribution

BED MEASUREMENTS
LENGTH WIDTH

OTHER BEARS #

DEPTH BED TREE D.B.H.

MARK TRAIL
LENGTH IMPRESSIONS

STATUS (circle 1 max)
1 Permanent
2 Seasonal

MARK TREE
SPECIES D.B.H. HT MARKED AGE

FOOD SPECIES (circle 1 to 4)

FOOD NAME & LABELS
SITE # FOOD SITE # FOOD SITE # FOOD SITE # FOOD

OTHER WILDLIFE
(circle 2 max)
1 Moose
2 Deer
3 Black Bear
4 Wolf
5 Wolverine
6 Other
SPECIFY

OTHER WILDLIFE USE
(circle 2 max)
1 Bed
2 Browse
3 Graze
4 Scat
5 Track
6 Dig & Peck
7 Other
SPECIFY

CONTINUE ON REVERSE

SITE INVESTIGATION FORM CONTINUED

DISTANCE MEASURES

TO OPENING m

HABITAT TYPE

TO COVER (m)

TYPE OF COVER

COVER VALUE
N E S W

COVER TYPE
N E S W

TO HUMAN ACT (m)

ACTIVITY TYPE
(circle 2 max)
1 None
1 Road
2 Clear Cut
3 Air Strip
4 Camp
5 Dry Land Sort
6 Spur Road
7 Other
SPECIFY

CURRENT USE
(circle 2 max)
1 None
1 Telemetry Vehicle
2 Cone Taker
3 Felling, Bucking
4 Yarding, Loading
5 Hauling
6 Spring
7 Road Construction
8 Full Operation
9 Other
SPECIFY

WITHIN ZONE ONLY

AXIS COVER VALVE

COVER TYPE

NOISE LEVEL

COMMENTS

TO WATER (m)

SALMON AVAILABILITY
(circle 1 max)
1 None
2 Low
3 Medium
4 High

SALMON ABUNDANCE
(circle 1 max)
1 None
2 Low
3 Medium
4 High

TO PREDOMINATE

DESCRIPTION

ASSOCIATED HABITAT (m)

HABITAT TYPE

COVER VALUE
N E S W

PHOTO #

FILM #

SCAT #

SITE DIAGRAM

N

COMMENTS

MAPPING GRIZZLY BEAR HABITAT IN GLACIER NATIONAL PARK USING A STRATIFIED LANDSAT CLASSIFICATION: A PILOT STUDY

Bart R. Butterfield and Carl H. Key

ABSTRACT: An existing Landsat classification, one of 20 data bases comprising a regional geographic information system, was used to create a first-generation map of grizzly bear habitat in the Two Medicine drainage of Glacier National Park, MT, and to assess the potential for using Landsat to produce a park-wide habitat map. A total of 189 Landsat classes, stratified by elevation and aspect, were grouped into 18 habitat classes significant to grizzly bears. Six forested habitat classes represented habitat types or combinations of habitat types that appeared to provide similar resources to grizzly bears. Other habitat classes generally corresponded with the widely accepted grizzly bear habitat component system. The stratified Landsat classification demonstrated a moderate capability to resolve the array of grizzly bear habitat classes. An improved classification may be achieved by restructuring the existing Landsat classification and incorporating relevant ancillary themes, such as time-since-burn and snow chute locations.

INTRODUCTION

Landsat analysis is widely recognized as a potentially powerful tool for mapping large expanses of wildlife habitat (Loffler and Margules 1980; Lyon 1983; Thompson and others 1980). Landsat has been applied to grizzly bear habitat mapping (Craighead and others 1982), but because it is often criticized for its low resolution and inaccuracy, it has been largely ignored for this use. Inadequacies have stemmed partially from sole reliance on the discriminating capabilities of Landsat data. Improved cover type classifications may be achieved through topographic stratification (Hoffer and others 1979; Justice and others 1981; Rhode and others 1979), but stratified Landsat classifications cannot, by themselves, sufficiently map grizzly bear habitat because habitat quality also depends on characteristics such as distance to water, time since last burn, and presence of snow chutes (Mealey and others 1977; Servheen 1983; Zager and others 1983). Those attributes cannot be detected by Landsat's spectral data alone and cannot be accurately represented by topographic data planes. To map grizzly bear habitat, relevant ancillary data themes must be incorporated into the habitat classification process along with the Landsat-derived cover type theme in the context of geographic information systems (Marble and Peuquet 1983; Wherry and others 1985).

The ultimate goal of this ongoing project is to develop a map of grizzly bear habitat in Glacier National Park and, possibly, seasonal maps. This paper presents the results of the first step toward that goal: a first-generation habitat map, derived from a stratified Landsat classification, in the Two Medicine drainage of Glacier National Park. We evaluate the map and recommend ways of restructuring the Landsat classification and improving the information content by incorporating ancillary data themes.

METHODS

The grizzly bear habitat classification developed in two stages (fig. 1). The first stage was a general, stratified Landsat classification. The second stage was application of the stratified Landsat classification to form the grizzly bear habitat classification.

Stratified Landsat Classification

The stratified Landsat classification used to map grizzly bear habitat existed as one of multiple layers in a geographic information system created jointly by Flathead National Forest and Glacier National Park (Wherry and others 1985). It was derived from MSS Landsat 3 data utilizing VICAR/IBIS, a batch image-processing software package (Hart and Wherry 1984). Processing was conducted through the Digital Image Analysis Laboratory, Washington State University.

We classified the four bands of spectral data into 99 spectral classes using a guided clustering approach (fig. 1). We generated an elevation plane from DMA digital terrain tapes with interpolation to 40-ft intervals and created an aspect plane with increments of 5 degrees from the elevation plane. Stratification of the elevation and aspect planes permitted us to generate output planes with increments deemed

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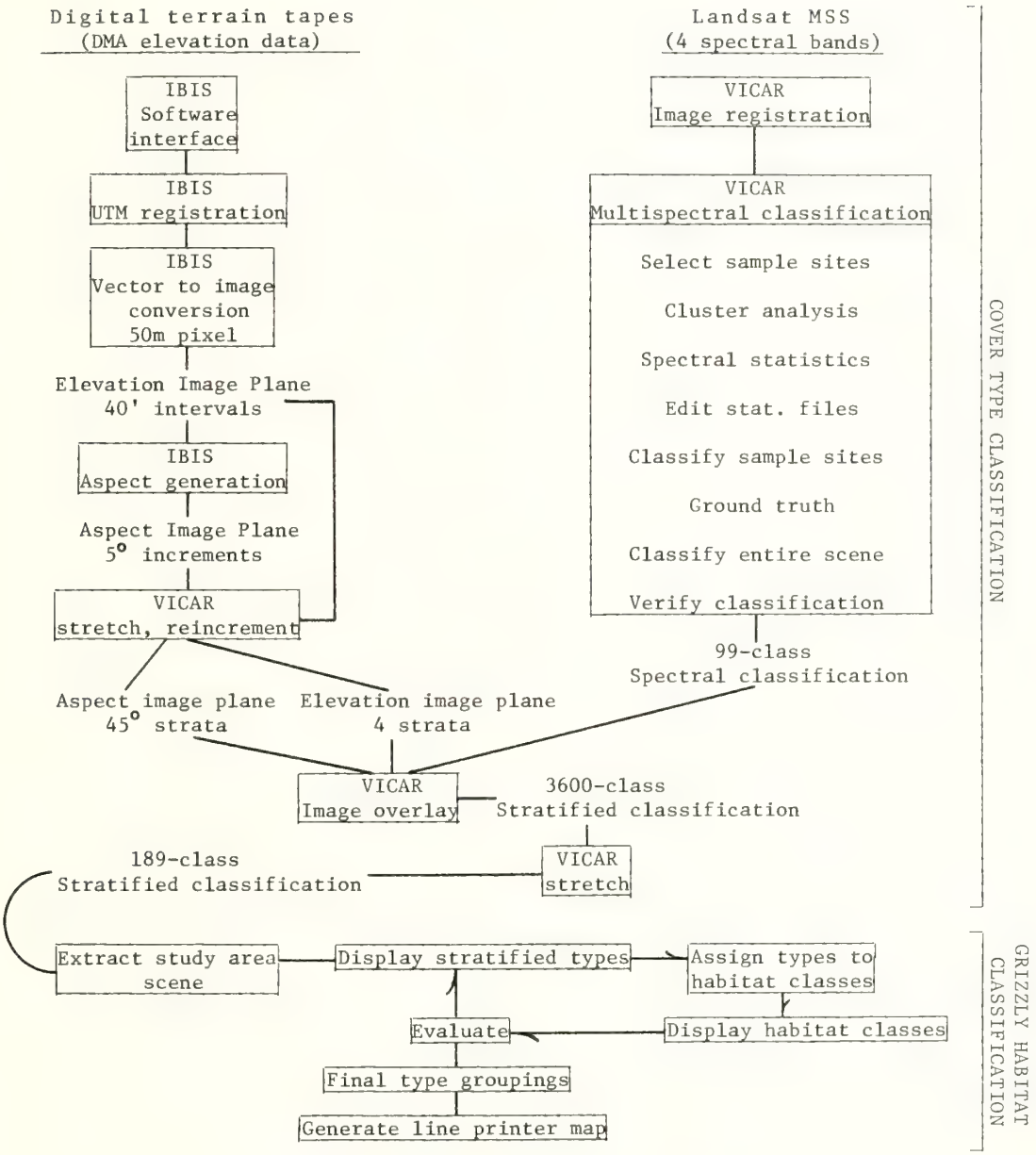


Figure 1.--A general flow chart of classification procedures.

suitable for mapping plant unions. Four strata were created for elevation and nine for aspect. All data planes were geometrically corrected and registered to the U.T.M. coordinate system.

The stratified Landsat classification was produced from the 99-type spectral classification, the four-strata elevation model, and the nine-strata aspect model. The initial classification contained 3,600 stratified classes and was reduced to 189 information types. A hierarchical legend of the stratified classification grouped similar Landsat classes according to discriminating characteristics and ordered them by relative discriminating power as follows:

WATER

Water type

SNOW

Snow type

LAND RESOURCES

Agricultural

Agricultural type (irrigated, nonirrigated, pasture, plowed)

Agricultural class within type

Barren lands

Moisture condition (dry, mesic, moist)

Elevation (lowland, subalpine to alpine)

Type of substrate

Natural vegetation

Major life form (coniferous forest, shrub, herbaceous)

Moisture condition (dry, mesic, moist)

Elevation (lowland, midelevation, subalpine, alpine)

Canopy closure or density (low, medium, high)

Species composition or character of exposed substrate

Plant vigor (especially, beetle-killed lodgepole pine)

Note that species composition is one of the lowest levels and is comparably unreliable for differentiating among types.

Grizzly Bear Habitat Classification

We derived grizzly bear habitat classes from the stratified Landsat classification. The term "habitat class" is used to avoid confusion over the popular term "grizzly bear habitat component." We do not imply that we used a fundamentally different classification. In fact, as will be pointed out later in this paper, many of our habitat classes correspond with established grizzly bear habitat components.

The process required interactive use of an image processor, the IIS System 511, and a Conrax RGB monitor. An image of the study area, a 512- x 512-pixel window (655 km^2), was displayed on the monitor. All Landsat classes within the image were sequentially displayed in color and the distribution of each noted on 1:30,000 scale, color infrared aerial photographs. A lengthy iterative process to group and regroup Landsat classes followed. Each group was assigned a pixel color and represented our concept of available grizzly bear habitat classes in the study area. The process ended when no further improvement in the habitat classification could be made with available information. We recorded final stratified Landsat class groupings and ran a batch job with VICAR/IBIS, creating a line printer map at 1:24,000 scale. The map encompassed the entire study area and represented the distribution of each habitat class with pixel symbols.

The line printer map was overlaid by a photomechanical transfer on transparent, copy-proof film of U.S. Geological Survey 7.5-minute topographic maps, which facilitated location in the field. After becoming familiar with vegetation in the study area, we found that some pixel symbols represented the same habitat class, so we combined those symbols to correspond better with actual habitat classes. We then outlined habitat classes on the overlays with a grease pencil as ground-truthing proceeded. These field overlays were traced onto frosted mylar. We overlaid negatives of this map and clean topographic maps to produce the final map, which is available from Glacier National Park, Research Office, West Glacier, MT, or Cooperative Park Studies Unit, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow.

Ground-truthing continued throughout the summer of 1984, concurrent with vegetation sampling. The objective of the sampling was to describe the representative vegetation and account for the full range of variation in each habitat class. Temporary, 375-m^2 plots were subjectively placed in representative stands. Plot allocation was proportional to the approximate availability of each habitat class and plot distribution covered a wide range of environmental conditions within each class. At each plot, pertinent map and physiographic data were recorded: line printer map symbol, sequential plot number, date, U.T.M. coordinates, habitat class, position on slope (ridgetop, upper slope, midslope, lower slope,

bench, or drainage bottom), ground configuration (flat, convex, concave, or undulating), elevation, slope, aspect, percent canopy closure, forest habitat type (if site was timbered) (Pfister and others 1977), and photograph identification number. A complete vascular plant species list was made, and percent cover of each species and rock, mineral soil, litter, deadfall, and nonvascular plants was visually estimated (Pfister and others 1977). Mean height of each species was also estimated.

Data were summarized using the Statistical Analysis System software package (SAS Institute Inc. 1982) at the University of Idaho. Constancy, mean percent cover, and mean height of each species was determined for each habitat class.

RESULTS

Twenty-two pixel types were derived from the stratified Landsat classification. Each was characterized by a major life form and canopy coverage. Some of these were regrouped during the field season, resulting in 18 grizzly bear habitat classes (table 1). Complete descriptions and technical data are available in Baldwin and others (1985). Seventeen of the 22 original pixel types strongly corresponded with specific habitat classes (table 2). The lack of correspondence in the remaining habitat classes can be attributed to the inherent insignificance of species composition in spectral classification or the classification of habitat classes representing transitional sites.

Six forested habitat classes represented habitat types or combinations of habitat types that appeared to provide seasonally distinct resources to grizzly bears (table 3). The most ubiquitous of the forested classes, the lower subalpine-open conifer, occurred on relatively warm, dry aspects and had the greatest plant species diversity of all habitat classes. The lower subalpine-closed conifer habitat class occupied most lower, north-facing slopes. The understory was poorly developed or consisted of dense stands of almost pure menziesia (Menziesia ferruginea). The upper subalpine-conifer habitat class formed the forested portion of cirque basins. Big huckleberry (Vaccinium membranaceum x V. globulare) dominated the shrub layer. The timberline habitat class was relatively dry and consisted of a very open canopy of stunted and deformed conifers. Extensive stands of the lodgepole pine habitat class resulted from the 1910 Dry Fork Fire. The understory was poorly developed, suppressed by a dense canopy. The spruce floodplain habitat class occupied floodplains with seasonally high water tables.

Nonforested habitat classes generally corresponded with established grizzly bear habitat components (Aune and others 1984; Servheen 1983; Zager and others 1983) (table 4).

DISCUSSION

Two problems were encountered that may have influenced the computer-generated habitat classification. First, an error in the aspect plane prevented discrimination between southerly and flat aspects and was not resolved before the mapping process. Second, the Landsat classification had only limited verification on the east side of the park, which differs botanically from the west side, and we were not personally familiar with the vegetation in the study area before the computer grouping process. Therefore, we found it necessary to form computer-generated habitat classes based on our knowledge of the Landsat classes on the west side of the park and our concept of grizzly bear habitat in the study area, as obtained from literature and aerial photos.

As a result, a one-to-one correspondence of original, Landsat-derived habitat class with final, regrouped habitat class was not obtained, in most cases. Each pixel symbol generally represented more than one habitat class, and each habitat class was often represented by more than one pixel symbol. We found, however, that habitat class boundaries, as indicated on the line printer map, were real. Ground-truthing simply involved identifying the actual habitat classes separated by the boundaries. With experience, we were able to identify habitat classes based on pixel symbol, topographic or physiographic position, and association with other pixel symbols and surrounding grizzly bear habitat classes.

The two problems noted above have now been resolved, and we believe that a more accurate, second-generation map can be made simply by restructuring the existing stratified Landsat classification. Requiring about 8 hours, the process would utilize the IIS System 511 interactive image processor and incorporate site information acquired since generating the first map.

Grizzly bears spend a great deal of time in timber (Aune and others 1984; Martinka 1972); however, current grizzly bear habitat mapping efforts fail to identify ecologically meaningful forest communities. The only forested grizzly bear habitat components are open and closed timber (Aune and others 1984; Servheen 1983; Zager and others 1983). Mealey and others (1977) evaluated the potential food value of forested habitat types for grizzly bears and concluded that, besides providing security cover, some habitat types had high food values. Our classification of forested areas generally corresponds to forested habitat types or combinations of habitat types that appear to provide similar resources (table 3). The lower subalpine-closed conifer habitat class included habitat types with low food values (Mealey and others 1977) and those used little by grizzly bears (Aune and others 1984). High food values were reported for habitat types associated with the lower subalpine-open conifer and upper

Table 1.--Grizzly bear habitat class characteristics

	Habitat class	Dominant species	Associated species	Topography	
1	Lower subalpine-open conifer	Subalpine fir Big huckleberry Beargrass	Utah honeysuckle Western meadowrue Cascade mountain-ash Lodgepole pine	Elev. Slope Aspect Position	5,000-6,680 feet 0-30 degrees All All
2	Lower subalpine-closed conifer	Menziesia Subalpine fir Spruce Beargrass	Big huckleberry Beadlily Foamflower Cascade mountain-ash	Elev. Slope Aspect Position	5,100-5,860 0-27 N (S, W) Lower, mid, bottoms
3	Lodgepole pine	Lodgepole pine Big huckleberry Beargrass Shiny-leaf spirea	Grass Spruce Heartleaf arnica Douglas-fir	Elev. Slope Aspect Position	4,900-5,650 0-30 S, W (NE) Mid, benches, bottoms
4	Upper subalpine-conifer	Subalpine fir Big huckleberry Beargrass Smooth woodrush	Mountain arnica Whitebark pine Menziesia Spruce	Elev. Slope Aspect Position	5,500-6,750 6-28 All Upper, mid, lower
5	Spruce floodplain	Spruce Western meadowrue Grass Common horsetail	Willow Subalpine fir Arrowleaf groundsel One-sided wintergreen	Elev. Slope Aspect Position	4,900-5,480 0 - Bottom
6	Timberline	Subalpine fir Sedge Whitebark pine Beargrass	Smooth woodrush Grass Big huckleberry Western meadowrue	Elev. Slope Aspect Position	5,900-7,100 5-40 All Mid, upper
7	Krummholz	Subalpine fir Spruce Whitebark pine	Cinquefoil Yellow hedysarum Grass Explorer's gentian	Elev. Slope Aspect Position	6,700-7,800 11-35 All Mid, upper
8	Cirque basin complex	Sedge Glacier lily False hellebore Arrowleaf groundsel	Indian paintbrush Subalpine fir Grass Aster	Elev. Slope Aspect Position	6,100-6,750 4-24 All Mid, lower, bottom
9	River floodplain	Black cottonwood Fireweed Swamp gooseberry Whiteleaf phacelia	Grass Yarrow Willow Hooker's thistle	Elev. Slope Aspect Position	4,950-5,900 0-5 - Bottom
10	Aspen	Aspen Western meadowrue Black cottonwood Common snowberry	Grass Western sweet-root Fireweed Showy aster	Elev. Slope Aspect Position	4,900-5,580 0-15 S, E Mid, lower, benches
11	Bunchgrass slope	Grass Pussytoes Silky lupine Kinnikinnick	Serviceberry Northern bedstraw Yarrow Sedge	Elev. Slope Aspect Position	5,250-6,250 10-35 S, E (N, NW) Upper, mid, lower
12	Mesic shrub	Beargrass Cascade mountain-ash Subalpine fir Big huckleberry	Fireweed Western meadowrue Shinyleaf spirea Grass	Elev. Slope Aspect Position	5,250-6,400 0-10 All Mid, lower

(con.)

Table 1. (Con.)

	Habitat class	Dominant species	Associated species		
13	Dry shrub/grass	Kinnikinnick	Aspen	Elev.	5,500-6,100
		Grass	Silky lupine	Slope	16-25
		Buffaloberry	Beargrass	Aspect	S, E
			Common juniper	Position	Mid, lower
14	Hydric shrub	Sitka alder	Grass	Elev.	5,250-5,800
		False hellebore	Sweet-scented bedstraw	Slope	5-26
		Stream violet	Stinging nettle	Aspect	All
		Western meadowrue	Arrowleaf groundsel	Position	Lower
15	Meadow	Grass	Sedge	Elev.	5,165-5,925
		Northern bedstraw	Pussytoes	Slope	0-10
		Roundleaf alumroot	Common horsetail	Aspect	-, (W)
		Strawberry	Yarrow	Position	Bench, bottom
16	Marsh	Willow	Grass	Elev.	4,900-5,200
		Sedge	Swamp gooseberry	Slope	0
		Bearberry	Common horsetail	Aspect	-
		Rush	Aster	Position	Bottom
17	Talus/rock/scree	Grass	Yarrow	Elev.	5,700-9,000
		Matted saxifrage	Lanceleaved stonecrop	Slope	13-90
		Cinquefoil	Elliptic-leaved penstemon	Aspect	All
				Position	Mid, upper, ridgetop
18	Vegetated talus/ rock/scree	Grass	Sedge	Elev.	5,520-8,000
		Cinquefoil	Lanceleaved stonecrop	Slope	5-35
		Yarrow	Yellow hedysarum	Aspect	All
		Northern bedstraw	Yellow buckwheat	Position	Mid, upper, ridgetop

Table 2.--Percentage of 22 original pixel symbols among 18 grizzly bear habitat classes[1]

Habitat class	Pixel Symbol																				
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1			20	20	11	80	57		75													
2	67			33																		
3	22			27			7															
4		100	20		22		14	100					25									
5			20		44		7				11	7		20								
6							7					7										
7										25		21										
8			20	13			7		13													
9											11	14				13						
10																31						
11					11									80	9	6	17		50			
12					11	20			13			14			82	6	50		17			
13												14					17		17			
14															9	25	17			100		
15				7							11	7				6			17			
16	11		20									7				13						
17											11							100			100	100
18										75	56	7	75									

[1]Pixel symbols are arbitrary symbols used on Landsat-derived line printer map. Habitat class numbers refer to table 1.

Table 3.--Distribution of forested habitat types among forested grizzly bear habitat classes, as number of plots sampled

Forested habitat class	Forested habitat type[1]											
	ABLA/ XETE/ VAGL	ABLA/ CLUN/ XETE	ABLA/ CLUN/ CLUN	ABLA/ CLUN/ MEFE	ABLA/ MEFE	ABLA/ CACA/ CACA	ABLA/ LUHI/ VASC	ABLA/ LUHI/ MEFE	Picea/ EQAR	ABLA/ GATR	PIAL- ABLA	LALY- ABLA
Lower subalpine-open conifer	10	3	2	1	4	1		1				
Lower subalpine-closed conifer		1	2	1	6							
Lodgepole pine	5	1	1									
Upper subalpine-conifer							5	3			1	
Spruce floodplain			1						2	2		
Timberline											8	1

[1]Pfister and others (1977).

Table 4.--Correspondence of habitat classes with established grizzly bear habitat components

	Habitat class	Grizzly bear habitat component[1]
1	Lower subalpine-open conifer	Closed timber, open timber, timbered shrubfield, timber
2	Lower subalpine-closed conifer	Closed timber, open timber, timber
3	Lodgepole pine	Closed timber, open timber, timber
4	Upper subalpine-conifer	Closed timber, open timber, timbered shrubfield, timber
5	Spruce floodplain	Closed timber, open timber, timbered shrubfield, timber
6	Timberline	Closed timber, open timber, timber
7	Krummholz	None
8	Cirque basin complex	Timber/meadow mixture
9	River floodplain	Riparian zone/complex, populus
10	Aspen	Populus
11	Bunchgrass slope	Mountain grassland, sidehill park
12	Mesic shrub	Shrubfield, snowchute, burns
13	Dry shrub/grass	Shrubfield
14	Hydric shrub	Shrubfield, snowchute
15	Meadow	Meadow
16	Marsh	Marsh, riparian shrub
17	Talus/rock/scree	Rock/talus/rubble/scree, slabrock alpine, slabrock--mid to low, ridgetop
18	Vegetated talus/rock/scree	Rock/talus/rubble/scree, slabrock alpine, slabrock--mid to low, ridgetop

[1]Aune and others (1984); Servheen (1983); Zager and others (1983).

subalpine-conifer habitat classes (Mealey and others 1977). Grizzly bear use of habitat types associated with these habitat classes and the timberline and spruce floodplain classes has been reported to be at least seasonally high (Aune and others 1984).

Our nonforested habitat classes generally correspond with established grizzly bear habitat components; however, several of our habitat classes need to be further refined or broken down into vegetation types within physiographic units, similar to the efforts of Mace (1984). For example, hydric shrub, mesic shrub, and dry shrub/grass habitat classes included snow chutes, snowslide surfaces, burns, and other shrubfields. Using stratified Landsat data alone, these types are not readily separable, but given the broad range of information types within the stratified Landsat classification (189 types) and available ancillary data, we believe that sufficient modifications can be made without reclassifying the raw Landsat data.

Snow chutes occur on all aspects, transect several elevation strata, and contain many distinct plant unions. Snow chutes could be mapped, however, by digitizing locations from quadrangle maps or by modeling their positions with slope and hydrologic data. Once the snow chute data base is developed, it could be digitally superimposed on the stratified Landsat classification to specifically identify vegetation types within snow chute reaches.

Like snow chutes, recent burns appear as other shrub-dominated sites within the Landsat classification. More precise mapping of burn-associated vegetation could be achieved if a time-since-last-burn or fire mosaic data base was developed and incorporated into the habitat mapping process. That base does not exist for the Two Medicine study area, but a suitable one has been developed for the North Fork of the Flathead River drainage within Glacier National Park (Key 1983).

Because of moderate spatial resolution, Landsat 3 data do not distinguish small areas, especially meadows and marshes surrounded by forests. Instead, these sites have to be mapped from aerial photos and their locations can then be digitally incorporated into stratified Landsat classifications with other ancillary themes.

Ancillary data, including slope and elevation, could also be used to help separate rock outcrops or cliffy areas from talus slopes that potentially harbor insects used by grizzly bears (Chapman and others 1953; Servheen 1983). It is well documented that grizzly bear feeding habits respond to the phenology of high-elevation plant foods brought about by melting snow cover (Martinka 1972; Servheen 1983). Elevation, stratified by criteria specifically relevant to grizzly bear habitat use, would be an important discriminating variable for mapping habitat on a seasonal basis. Ongoing research on grizzly bear feeding habits in Glacier National Park may provide the necessary criteria (Kendall 1985).

Distance from water is another ancillary theme that would permit more precise mapping of vegetation types associated with riparian zones. Distance-from-water data bases exist for the Flathead/Glacier geographic information system and identify corridors, classified by stream order and water type (for example, lake, intermittent stream, perennial stream) at 150-m intervals from all points occupied by surface water to a distance of 1.3 km (Key and others in preparation).

It is our opinion, based on evaluation of the first-generation map, that a stratified Landsat classification definitely can help resolve the array of grizzly bear habitat classes; however, to achieve truly representative habitat maps, future mapping attempts should incorporate relevant ancillary themes. Once ancillary data bases are compiled in digital formats, and the criteria for applying those data to grizzly bear habitat classification become known, the process of incorporating those informational themes in the mapping exercise is almost trivial.

In the future, the need will arise to develop general, stratified classifications which maximize information content over the full range of surface types (Key in preparation). It will no longer be efficient or cost effective to develop cover type classifications for every specific application. Users with special objectives, such as grizzly bear habitat mapping, will apply their expertise to combine stratified Landsat classes into habitat classes that satisfy their unique needs. Landsat supplies one information source toward developing such classifications, as do topographic, precipitation, human activity, and other ancillary themes.

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AN ECOLOGICAL TAXONOMY FOR EVALUATING GRIZZLY BEAR HABITAT IN THE WHITEFISH RANGE OF MONTANA

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ABSTRACT: An ecological classification of forest habitat is presented and a method of grizzly bear habitat assessment discussed. Land area is classified by habitat type, successional stage, and community type. Community types are defined and described. The framework of a grizzly bear habitat use model based on community type distribution and food habits data is offered. Model refinement is possible as phenological, disturbance, and local bear information become available.

INTRODUCTION

Classification and evaluation of grizzly bear (Ursus arctos) habitat have progressed from simpler descriptive terms (Zager and others 1980; USDA Forest Service 1979; Madel and Christensen 1982) to a more ecologically based analysis (Craighead and others 1982). The development of a grizzly bear habitat use model based on a hierarchy of ecological land classifications and a promising interpretation of the forest mosaic as grizzly bear habitat are the focus of this paper. The benefits of such an ecological approach are several: (1) each part of the analysis dovetails with other levels, (2) interpretation is unified and standardized, (3) refinements are possible as more information is obtained, and (4) completed vegetation maps can be used for interpreting vegetation in adjacent areas using LANDSAT imagery and Geophysical Information System (GIS) techniques.

BACKGROUND

There are essentially two approaches to wildlife habitat classification. The first and most widely used approach has been to characterize wildlife habitat according to broadly defined vegetative classes. For this type of classification, intensive sampling is not required. A major drawback is that the classes are usually broad, and the vegetative variability is not described. Consequently, predictability of habitat suitability, plant species occurrence, and structure is low.

The second and more recent approach to wildlife habitat analysis is based on quantitative analysis of vegetation. This classification requires vegetation sampling, and classes are developed from these data. Derived statistics describe the variability of certain indicator species, and this variability can then be standardized. Although this form of classification requires more effort to develop, its high degree of predictability provides a much more useful classification.

Classification of potential or climax plant communities as defined by Daubenmire (1968) is fairly common throughout the western United States. These "associations" are the basis for the habitat type stratification (Pfister and others 1977; Mueggler and Stewart 1980; Cooper and others 1985). This system has been valuable to land managers for stratifying land potential, categorizing productivity, correlating environmental characteristics with vegetation, and formulating general management regimes; however, most existing vegetation in the Northern Rocky Mountains is in a seral state and the association information is not very useful for describing wildlife habitat suitability.

Existing seral vegetation can, however, be classified into community types and correlated with the type and time since disturbance within the habitat type framework. This approach has proved valuable for multiresource interpretations. Various approaches have been described by Hurschle and Hironaka (1980), Hann (1982), Steele (1984), and Arno and others (1985).

Once successional pathways are understood, a model can be developed for each habitat type. Model predictions are based on existing vegetation data, treatment type, and treatment intensity. The model predicts the resulting vegetation composition over time for each treatment. Alternative vegetation treatments, such as wildfire, broadcast burn, or clearcut/broadcast burn, can be evaluated for short- and long-term desirability for a given wildlife species.

This study is based on the assumption that grizzly bears make discrete choices of the plant food items consumed and, therefore, that availability and abundance of food items are key factors in

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habitat selection by the bear. In addition, habitat attributes offered by the forest mosaic influence this selection. The driving hypothesis of this study is that ecologically defined and mapped community types can be used to accurately predict intraseasonal and interseasonal grizzly bear movement within the forest mosaic.

STUDY AREA

The study area comprises the southern end of the Whitefish Range (lat. 48°30' N., long. 114°15' W.) approximately 8 mi (12.8 km) north of Columbia Falls, MT. Elevation ranges from river benchland at 3,200 ft (973 m) to a few upper subalpine peaks at 7,000 ft (2 133 m). Nine forest habitat types and various phases (Pfister and others 1977) in the subalpine-fir climax series occur over the area. Grassland habitat types (Mueggler and Stewart 1980) occur along high ridges with a southern exposure. Various disclimaxes associated with avalanche chutes and wildfires occur throughout the study area. In addition, much of the study area has been affected by humans. Extensive road construction in all major drainages and subdrainages preceded commercial logging operations, which began in the 1950's. Climate is classified as Pacific Maritime. Big Mountain in the westcentral portion of the study area receives up to 100 inches (254 cm) of precipitation per year, mostly as snow. The study area is approximately 45 mi^2 (155 km^2).

METHODS

The area was initially stratified by mapping habitat types (Pfister and others 1977; Mueggler and Stewart 1980) and successional stages for forest stands (modified from Arno and others 1985) on 1:16,000 color aerial photographs. Seven successional stages were used to stratify forest variation: (1) grass-forb, (2) shrub-seedling, (3) sapling, (4) pole, (5) young, (6) mature, and (7) old growth. Forest stands were delineated by any distinct change in cover type and represent areas of relatively homogeneous cover or density. Information from the Flathead National Forest timber stand data base was used to generate the preliminary habitat type by seral stage units, which were mapped on orthophotos. Information selected from this data base included habitat type, tree density, height, and age of stand. For photo interpretation work, density was interpreted by canopy cover values. Canopy cover values were modified from Arno and others (1985). Using this method, 100 percent of the study area was initially mapped to habitat type and successional stage.

A rapid reconnaissance method was employed to gather data. This approach emphasized "characterizing" stands (Arno and others 1985; O'Brien and Van Hooser 1983) based on dominant species' cover values. Our approach was to estimate total canopy cover for each major plant species and all bear food plant species present in the stand. The entire stand was considered a "macro" plot. We walked through this stand once to note species and relative abundance. If a stand was particularly large or complex, we did a second walk-through. Occasionally a stand consisted of a mosaic of small, diverse communities. In such stands, we examined each distinct community separately while the mosaic was mapped as a single unit. Estimates of total cover for each species were made at the conclusi of the second pass. Coverage classes were based on a 10-point system:

Code	Percent canopy cover
0	0-1
1	2-4
2	5-10
3	11-20
4	21-30
5	31-40
6	41-50
7	51-60
8	61-70
9	71-80
10	81-100

Additional variables measured in each stand are as follows:

For trees:

- Height of dominant trees
- Total cover all trees
- Density (number of trees within a circle with radius of 25 ft)
- Canopy cover for individual tree species:
  - <5 inches d.b.h.
  - >5 inches d.b.h.

For shrubs, forbs, and grasslike plants:

- Life form
- Vitality
- Canopy cover for each life form
- Canopy cover for dominant species and bear food plant species for the entire stand
- Structural layer (0-1.5 ft, 1.5-6.1 ft, 6.1 ft +) of each taxa

We sampled stands in the grass-forb and shrub-seedling stages in 1984 and will sample stands in the midsuccessional stages (sapling, pole, and young) in 1985. Published values for canopy cover and constancy were used to describe mature and old-growth forest stands (Pfister and others 1977).

Analysis of the field data and interpretation of the resulting community type map as grizzly bear habitat occur in three stages, which are described in the following paragraphs. Because this study is ongoing, an example of a community classification will be presented in the Results section and other elements of the analysis will be discussed hypothetically in the Discussion section.

Community Type Classification

Stand data are examined and stands classified to community types. Cornell ecology programs TWINSPAN (Hill 1979a) and DECORANA (Hill 1979b) are used for the initial data sorting and classification. Species presence and canopy cover are the criteria used. Subjective evaluation of stand location, history, treatment, and other factors is also used to make successive groups of stands and a final classification (Gauch 1982; Pfister and Arno 1980).

Determining Grizzly Bear Food Habits

As a second step in the analysis, grizzly bear foods are determined from the literature and from scat records compiled from the study area and adjacent areas.

Interpretation of Community Types as Grizzly Bear Habitat

The final step is constructing a spatiotemporal model of grizzly bear habitat use based on community type distribution, food habits data, and food availability. Bear foods are ranked in importance by 1-month intervals. The presence and abundance of foods are then compared among community types, and community types are ranked in importance as foraging areas to grizzly bears.

RESULTS

Community Type Descriptions

The following community type (c.t.) classification and community type descriptions are preliminary. Community boundaries were determined from perceived environmental and structural differences. The descriptions that follow highlight major differences in dominant species. Sixteen c.t.'s were identified in the analysis of 131 stands. For brevity, only 2 of the 16 c.t.'s will be described here; all 16 are used in the analysis. A dichotomous key to the c.t.'s is presented in appendix A-1. Physical data are presented in appendix B-1. Stand data are not included for brevity. In the descriptions that follow, terms are defined as follows: present = 0 percent, common = 1 percent, well represented = 5 percent, abundant = 25 percent (after Pfister and others 1977).

The c.t.'s in this analysis fall within the *Abies lasiocarpa/Clintonia uniflora* habitat type. Within the study area considerable human-caused disturbance has occurred, including various silvicultural treatments and road-building. Natural disclimaxes include avalanche chutes and areas affected by wildfire. Only stands in the earlier successional stages (grass-forb and shrub-seedling stages) are presented to simplify the presentation of the relevant concepts. These concepts include (1) the nature of the community type classification, (2) the possibilities for interpreting community types as grizzly bear habitat, and (3) the potential for understanding how grizzly habitat may be created or enhanced by land management practices.

1. *Alnus sinuata/Claytonia lanceolata* c.t. (n=5): This community type is created by overstory removal. Elevation ranges from 3,800 to 4,350 ft and aspect is predominantly easterly. Tree overstory is generally depauperate. The shrub overstory is strongly dominated by alder (mean cover, 59 percent). *Acer glabrum* is also well represented, as is *Rubus parviflora*. *Vaccinium globulare* is common in most stands (70 percent). *Claytonia lanceolata* is abundant (27 percent), and *Smilacina racemosa* is common in all stands in the understory.

2. *Salix* spp./*Symphoricarpos albus* c.t. (n=8): Tree regeneration is good in this community type following clearcutting. Overstory constancy is moderate to high, and canopy cover is generally greater than 5 percent. The shrub overstory is dominated by *Salix scouleriana*; the shrub midstory is dominated by *Symphoricarpos albus*. Most other shrub species common to the study area are also present. Dominant forbs in the understory include *Epilobium angustifolium*, *Smilacina stellata*, and *Viola glabella*.

DISCUSSION

Vegetation that is disturbed from its climax condition is highly complex and variable. This complexity is usually greater the younger the stand is successionally (Hurschle and Hironaka 1980). Environmental variability as expressed by the vegetation can be understood by systematic classification of habitat types and community types. Stands of similar habitat type, structure, and species composition are grouped together, which permits identification of environmental and habitat differences. An animal's use of habitat can then be quantified.

The theoretical framework of our interpretation is perhaps best understood if viewed graphically (fig. 1). The analysis is composed of three parts: (a) food habits analysis, (b) food plant availability, and (c) the ranking of community types based on percent constancy and percent canopy cover of "preferred" food items. Each of these factors is assessed at an interval of time (for example, 1 month, 2 weeks). The prediction of c.t. importance value ("c" in fig. 1) is thus incremental through the foraging seasons (here denoted as "premast," "mast," and "postmast" seasons).

Certain assumptions are made in this analysis:

1. The importance value of food items determined from scat analysis accurately reflects the importance of that food item to the bear in that time period.

2. The food item availability in a particular c.t. is correctly predicted by phenological data.

3. A grizzly bear "selects" discrete c.t.'s based on the constancy and abundance of preferred plant food items, regardless of c.t. size.

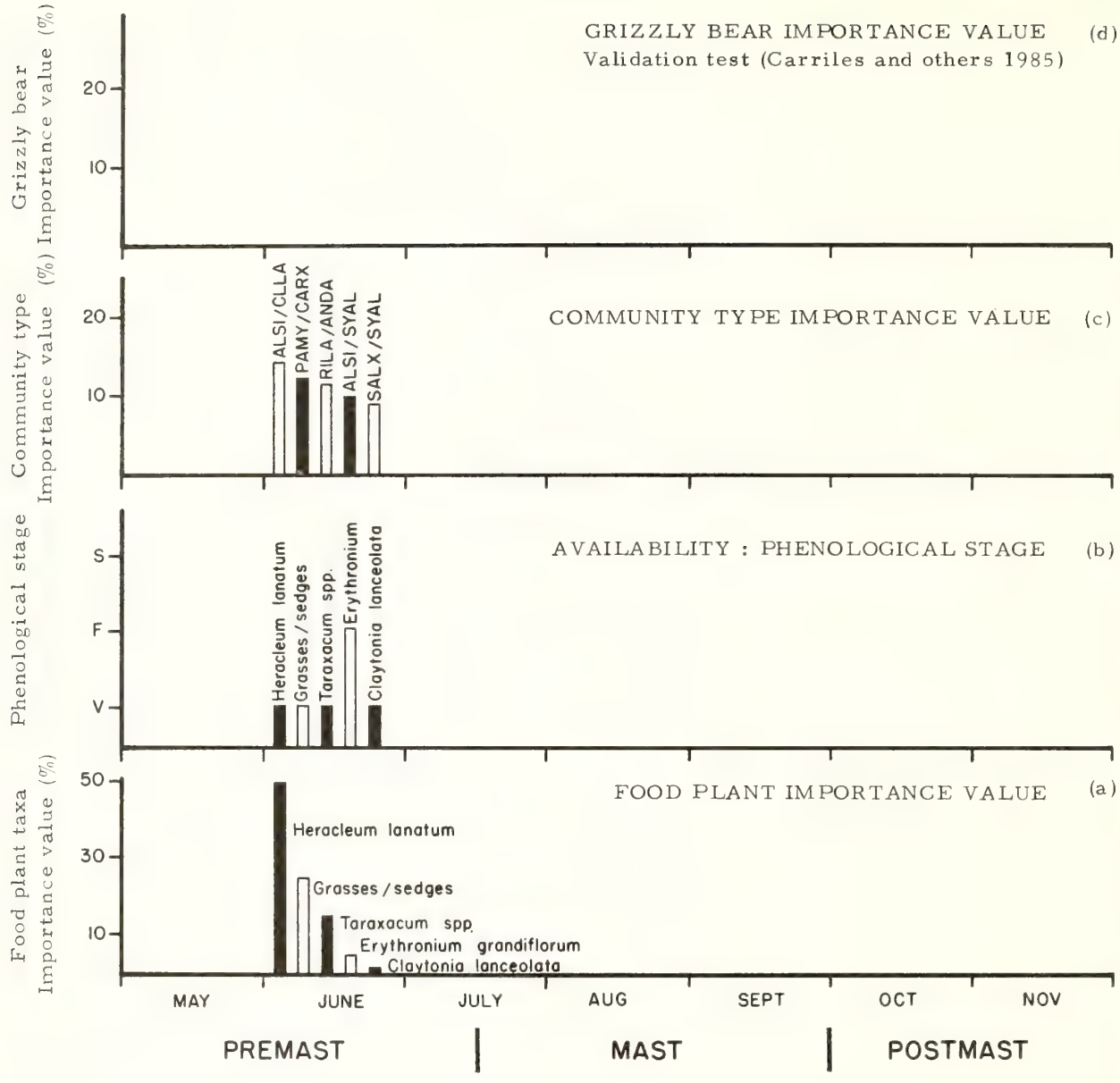


Figure 1.--The theoretical framework for the analysis, interpretation, and testing of community types (c.t.'s) as predictors of grizzly bear habitat suitability. The period of analysis is June. (a) Five bea foods are ranked by importance value. (b) Phenological availability (v = vegetative stage, f = flowering stage, s = seed set stage). (c) Community type importance value determined from food species importance value and phenological availability. Predictions of temporal and spatial use of habitat are made from subjective interpretations of (c). (d) Model predictions are tested in a separate study, using radio-location points; results are used to refine model predictions (Carriles and others 1985).

Figure 1 was constructed from actual and hypothetical data to illustrate the method of analysis. These values are determined as follows:

Food plant taxa importance value percentages (IV percent) are calculated first. Importance value is calculated from the percent frequency and percent volume of food items in scat material. The specific formula is:

$$IV\ \% = \frac{(\text{Frequency } \% \times \text{Volume } \%)}{(\text{Frequency } \% \times \text{Volume } \% \ / \ 100)} \times 100$$

Only those food items with an importance value of more than 1 percent are used in the subsequent ranking of c.t.'s. The following tabulation presents selected plant food species (from Mace 1984) and hypothetical importance values for the month of June:

Taxa	IV Percent
Heracleum lanatum	50
Grasses and sedges	25
Equisetum spp.	15
Taraxacum spp.	5
Erythronium grandiflorum	3
Claytonia lanceolata	1
Other forbs	1

Phenological availability of important taxa (fig. 1b) is determined next (Carriles in preparation). Phenological availability is strongly modified by elevation and aspect. In this example, it is expressed by three stages: vegetative growth, flowering, and seed set. As figure 1 shows, all taxa are available in the vegetative state in June, with the exception of Erythronium grandiflorum, which is flowering. Availability takes a value of 0 or 1,000 (absent or available, respectively; multiplying by 1,000 results in a linear transformation of the data).

Taxa constancies and canopy cover values summarized from field data are obtained from c.t. summary tables. The following data are derived from plant taxa in the Alnus sinuata/Claytonia lanceolata c.t. of the Abies lasiocarpa habitat type, southern Whitefish Range study area (N = 5).

Trees:

Abies lasiocarpa	5(12)[1,2]
Picea engelmanni	5(2)
Pinus monticola	2(1)
Populus trichocarpa	2(1)

Shrubs:

Acer glabrum	7(15)
Alnus sinuata	10(59)
Amelanchier alnifolia	2(3)
Lonicera involucrata	2(3)
Lonicera utahensis	2(3)
Menziesia ferruginea	2(1)
Oplopanax horridum	2(1)
Pachistima myrsinites	7(3)
Ribes lacustre	7(3)
Rubus parviflora	10(6)
Salix spp.	2(8)
Sambucus racemosa	10(4)
Sorbus spp.	10(16)
Vaccinium globulare	7(2)

Graminoids:

Gramineae	10(8)
Luzula parviflora	2(3)

Forbs:

Achillea millefolium	2(0)
Anaphalis margaritacea	2(3)
Angelica dawsonii	5(3)
Arnica latifolia	2(35)
Athyrium felix-femina	10(7)
Claytonia lanceolata	7(27)
Clintonia uniflora	5(2)
Disporum hookeri	5(9)
Epilobium angustifolium	5(14)
Erythronium grandiflorum	7(13)
Frageria virginiana	2(8)
Galium trifolium	5(2)
Heracleum lanatum	10(6)
Osmorhiza chilensis	7(5)
Pedicularis bracteosa	2(1)
Pteridum aquilinum	5(4)
Senecio triangularis	7(4)
Smilacina stellata	5(3)
Streptopus amplexifolius	2(3)
Taraxacum spp.	2(8)
Tellima grandiflorum	2(25)
Thalictrum occidentale	7(4)
Tiarella trifoliata	2(3)
Urtica dioica	5(3)
Veratrum viride	10(3)
Viola glabella	10(25)

[1]First figure indicates percent constancy: 0 = 0-5, 1 = 5-15, 2 = 15-25, 3 = 25-35, 4 = 35-45, 5 = 45-55, 6 = 55-65, 7 = 65-75, 8 = 75-85, 9 = 85-95, 10 = 95-100

[2]Figure in parentheses indicates percent canopy cover.

The c.t. importance value (CTIV) is calculated using importance value percents (IV percent) of "preferred" foods, canopy cover, constancy, and phenological availability. With these values the c.t. importance value is calculated as follows for all taxa:

$$CTIV = \Sigma\{(\%\ \text{canopy cover} \times \%\ \text{constancy}) \times (\text{IV }\%)(\text{availability})\}$$

Values are summed across all taxa in the time period with an IV percent greater than 1. A relative CTIV is calculated by dividing individual CTIV's by the sum of all CTIV's for the habitat type and then multiplying by 100.

Table 1 presents importance values and ranks for all 16 c.t.'s in the Abies lasiocarpa/Clintonia uniflora habitat type. During June, Heracleum lanatum and grasses are the most important food items.

The IV percent for grasses, as determined from our hypothetical data, was 25 (see list in Methods); however, calculations of CTIV's with grasses held at this value produced intuitively meaningless results. All c.t.'s contain grasses with moderate-to-high cover and constancy values. When these grass values are calculated, differences between c.t.'s, based on more important diagnostic and bear foods, become obscured. For this reason the IV percent for grasses was uniformly reduced by two thirds. The resulting calculations (table 1) discriminate more between c.t.'s. Other studies have eliminated grasses from calculations altogether for similar reasons (for example, Mace 1984). Even when reduced, however, grasses continued to strongly influence the ranking of types.

Table 1.--Calculated community type importance values (CTIV), and relative importance values for 16 community types (c.t.) in the Abies lasiocarpa/Clintonia uniflora h.t., southern Whitefish Range study area

Taxa	Community type															
	VAGL/ XETE	XETE/ CAAP	ACGL/ MEFE	ALSI/ SYAL	ALSI/ CLLA	SALX/ SYAL	SALX/ CARX	SALX/ THOC	PAMY/ SMST	PAMY/ CARX	ANDA/ SETR	MEFE/ VAGL	RILA/ ATFE	RILA/ ANDA	MEFE/ EPAN	MEFE/ GYDR
Heracleum lanatum	-	-	5.00	38.05	29.25	3.00	-	0.38	12.52	28.52	16.08	0.38	14.63	10.50	3.00	10.50
Grasses and sedges	4.04	21.55	.25	20.79	6.44	41.75	10.19	18.81	7.57	33.80	24.13	4.79	24.93	44.88	20.11	13.20
Equisetum spp.	-	-	-	.90	-	6.10	-	.90	.90	6.00	1.80	-	2.70	11.90	-	-
Taraxacum spp.	-	-	-	-	.40	-	-	.04	.03	-	-	-	.10	.30	.01	.04
Erythronium grandiflorum	.75	1.74	4.14	3.78	2.34	-	-	-	.12	-	.96	.01	-	-	.02	.45
Claytonia lanceolata	-	.01	2.44	.50	1.62	-	-	-	.02	-	.04	.03	-	-	-	.09
IV total	4.79	23.30	11.83	64.02	83.06	50.85	10.19	20.51	21.16	68.32	43.01	5.21	42.36	67.58	23.14	34.78
Relative percent IV	0.8	4.1	2.1	11.2	14.4	8.9	1.8	3.6	3.7	11.9	7.5	0.9	7.4	11.7	4.0	6.1
Rank	16	9	13	4	1	5	14	12	11	2	6	15	7	3	10	8

The results of the c.t. ranking (table 1) are intuitively acceptable to a degree. The five top-ranked c.t.'s fit our preconceived notion of rank, but the order of rank within those five did not. The Alnus sinuata/Symphoricarpos albus c.t. (rank 4) is similar to the Alnus sinuata/Claytonia lanceolata c.t. (rank 1). Heracleum lanatum, the "preferred" food item, is more abundant in the former. Here the abundance of grasses in the ALSI/CLLA c.t. resulted in a decided difference in rank. From what little is known about grizzly bear food habits and the combination of variables that grizzly bears "select" for, such a ranking could be representative.

It may well be that grizzly bear use of c.t.'s will exhibit a "breaking function" where c.t. use falls off rapidly at some certain low value of the product of constancy and cover. The model assumes that this is the case; however, no data exist to indicate where this point lies. The CTIV formula can be modified to account for such an effect once identified. The values in table 1 represent a fraction of the values that would be calculated for the study area. Other habitat types would be evaluated in the same way, and their CTIV's compared against all others. A breaking function phenomenon would greatly reduce the number of c.t.'s in the analysis.

A final ranking of c.t.'s would result in a number of c.t.'s, or "complexes" of c.t.'s (Mace 1984), for each period of analysis. These c.t.'s, ranked in importance by time period and arranged along the horizontal axis of figure 1c for all foraging seasons, would constitute a habitat use model. The validity of such a model rests on its being able to predict bear use of a particular c.t. at a particular time, regardless of whether all stands of that type are used. This is because the proportion of stands of a particular c.t. used may reflect bear numbers or social partitioning of habitat. A resource in excess does not necessarily imply that the resources provided by that c.t. are any less vital to the animal (Lyon 1985).

Finally, these predictions can be readily tested by radio-collaring a significant portion of a local population in a mapped area. Alternately, accurate historical radio-telemetry data could be used to validate predictions and improve model performance for management purposes (Carriles and others 1985).

CONCLUSIONS

Various methods of interpreting the foraging quality of grizzly bear habitat have been devised (for example, Madel and Christensen 1982; Craighead and others 1982; Mace 1984). In general, however, these interpretations remain the weakest part of our understanding of grizzly bear-habitat dynamics. In the Scapegoat Mountains, Craighead and others (1982) based their interpretations on observed bear behavior and are reliably accurate. The method employed in mapping and assessing habitat in the remainder of the Northern Region of the National Forest System (the grizzly bear habitat component system; Zager and others 1980) was based on bear locations, feeding sites analyses, and food habits. Subsequent work, however, relied upon these data which were extrapolated to areas that were remote from their place of origin (for example, Madel and Christensen 1982).

The recently developed cumulative effects model (CEM) for the Yellowstone Ecosystem (USDA Forest Service 1985) attempts to assimilate habitat quality interpretations into a dynamic model that makes predictions about the effects of human activities on the bear. This modeling effort relies on an extensive data base spanning some 2 years. A similarly designed CEM is being developed for the northern ecosystem without suc

an extensive data base. Nevertheless, cumulative effects modeling holds great potential for coming to grips with an often acrimonious debate over the grizzly bear and resource use.

We have attempted to illustrate the utility of presenting grizzly bear habitat as a mosaic of ecologically and hierarchically defined community types. An advantage of this approach is the possibility of improving predictions as additional information becomes available. Improved plant phenological data will enable better assessment of c.t.'s at different elevational zones. Radio-telemetry data should reveal not just point locations but the mosaic of c.t.'s or characteristics actually sought by the bear (Lyon 1985; Carriles and others 1985). Behavioral data obtained from radio-locations will suggest the social mechanisms enforcing any particular partitioning of resources by age or sex class. Tendencies for bears to migrate to seasonally abundant food sources (for example, grizzly bear concentrations on Apgar Mountain in Glacier National Park; Kendall 1984) can also be interpreted and incorporated into the model.

The CEM is a useful evaluation tool. It is important to use reliable data in its construction and refinement. In this paper we have proposed that the basis for obtaining these data is through developing and interpreting ecological vegetation maps. An ecological taxonomy provides a solid foundation for current work and improvements into the future.

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ppendix A.--Dichotomous key to community types in the ABLA/CLUN habitat type of the southern Whitefish Range study area

A. Alnus sinuata <2 percent, Sambucus racemosa <2 percent, and Carex spp. ≥2 percent and Xerophyllum tenax ≥5 percent . . . . . B		
A. Alnus sinuata and Sambucus racemosa >2 percent, Carex spp. <2 percent, or Menziesia ferruginea ≥5 and Vaccinium globulare >2 percent C		
B. Calochortus apiculatus ≥2 percent, Pinus monticola absent . . . . . B		Xerophyllum tenax/Calochortus apiculatus c.t.
B. Pinus monticola present and Calochortus apiculatus absent, then also Vaccinium globulare ≥2 percent . . . . . BB		Vaccinium globulare/Xerophyllum tenax c.t.
C. Smilacina stellata ≥2 percent with Menziesia ferruginea <5 percent and/or Symphoricarpos albus <1 percent . . . . . D		
C. Smilacina stellata <2 percent, Menziesia ferruginea ≥5 percent, and Symphoricarpos albus <1 percent . . . . . K		
D. Larix occidentalis absent and/or Salix spp. absent, Alnus sinuata >10 percent, and Pachistima myrsinites <5 percent . . . . . E		
D. Larix occidentalis present and/or Salix spp. present, Alnus sinuata ≤10 percent, and Pachistima myrsinites ≥5 percent . . . . . G		
E. Menziesia ferruginea ≥2 percent and Acer glabrum ≥20 percent . . . . . E		Acer glabrum/Menziesia ferruginea c.t.
E. Menziesia ferruginea <2 percent with Acer glabrum <20 percent . . . . . F		
F. Vaccinium globulare absent, Claytonia lanceolata <2 percent, and Pachistima myrsinites <2 percent . . . . . F		Alnus sinuata/Symphoricarpos albus c.t.
F. Vaccinium globulare ≥1 percent, Claytonia lanceolata ≥2 percent, and Pachistima myrsinites ≥2 percent . . . . . FF		Alnus sinuata/Claytonia lanceolata c.t.
G. Gymnocarpium dryopteris and Heracleum lanatum absent . . . . . H		
G. Gymnocarpium dryopteris and Heracleum lanatum both present, Pachistima myrsinites generally present . . . . . J		
H. Clintonia uniflora absent, or Ranunculus uncinatus and Symphoricarpos albus ≥2 percent with Salix spp. ≥2 percent . . . . . H		Salix spp./Symphoricarpos albus c.t.
H. Clintonia uniflora present and Salix spp. ≥2 percent I		
I. Arnica latifolia and Thalictrum occidentale <2 percent, Anaphalis margaritacea absent; Carex spp. ≥2 percent I		Salix spp./Carex spp. c.t.
I. Arnica latifolia and Thalictrum occidentale ≥2 percent, Anaphalis margaritacea present II		Salix spp./Thalictrum occidentale c.t.

Appendix A. (Con.)

J.	Smilacina racemosa present and Epilobium angustifolium ≥2 percent with Pachistima myrsinites ≥2 percent	J	Pachistima myrsinites/ Smilacina stellata c.t.
JJ.	Smilacina racemosa and Populus trichocarpa absent and Carex spp. ≥5 percent	JJ	Pachistima myrsinites/ Carex spp. c.t.
K.	Equistum spp. <1 percent and Pachistima myrsinites or Gymnocarpium dryopteris present	M	
KK.	Equisetum spp. ≥1 percent, Pachistima myrsinites and Gymnocarpium dryopteris generally absent, and Angelica dawsonii present	L	
L.	Streptopus amplexifolius present and Luzula parviflora present with Ribes lacustre ≥2 percent	N	
LL.	Streptopus amplexifolius absent and Habenaria spp. and Gymnocarpium dryopteris absent	LL	Angelica dawsonii/Senecio triangularis c.t.
M.	Ribes lacustre and/or Rubus parviflora present, and/or Epilobium angustifolium ≥2 percent	O	
MM.	Ribes lacustre, Rubus parviflora or Epilobium angustifolium absent; Menziesia ferruginea ≥5 percent and Vaccinium globulare ≥2 percent	MM	Menziesia ferruginea/Vaccinium globulare c.t.
N.	Athyrium felix-femina, Gymnocarpium dryopteris and Tiarella trifoliata present	N	Ribes lacustre/Athyrium felix-femina c.t.
NN.	Athyrium felix-femina, Gymnocarpium dryopteris, and Tiarella trifoliata absent	NN	Ribes lacustre/Angelica dawsonii c.t.
O.	Xerophyllum tenax ≥2 percent and Gymnocarpium dryopteris <2 percent with Alnus sinuata ≥2 percent	O	Menziesia ferruginea/Epilobium angustifolium c.t.
OO.	Xerophyllum tenax <2 percent, and Gymnocarpium dryopteris ≥2 percent with Menziesia ferruginea ≥2 percent	OO	Menziesia ferruginea/ Gymnocarpium dryopteris

Appendix B.--Summary of physical data for some community types in the *Abies lasiocarpa/Clintonia uniflora* habitat type in the southern Whitefish Range study area

Community type	Elevation (ft) (Min-Max)	Elevation (ft) Mean	Aspect (degrees) (Min-Max)	N
Xerophyllum tenax/ Calochortus apiculatus	(4,050-6,000)	5,220	(78-260)	6
Vaccinium globulare/ Xerophyllum tenax	(5,550-6,775)	6,171	(110-145)	6
Acer glabrum/ Menziesia ferruginea	(4,700-5,300)	4,944	(240-270)	4
Alnus sinuata/ Symphoricarpus albus	(4,350-5,450)	4,900	(135-200)	2
Alnus sinuata/ Claytonia lanceolata	(4,050-5,350)	4,938	(55-150)	4
Salix spp./ *Symphoricarpus albus*	(3,800-4,350)	4,069	(80-355)	8
Salix spp./ *Carex* spp.	(3,900-4,900)	4,275	(55-240)	5
Salix spp./ *Thalictrum occidentale*	(4,150-5,200)	4,682	(60-220)	7
Pachistima myrsinites/ Smilacina stellata	(3,800-5,900)	4,308	(20-350)	29
Pachistima myrsinites/ Carex spp.	(4,300-4,600)	4,450	(140-180)	2
Angelica dawsonii/ Senecio triangularis	(5,300-6,200)	5,750	(25-125)	2
Menziesia ferruginea/ Vaccinium globulare	(3,925-5,400)	4,765	(25-165)	5
Ribes lacustre/ Athyrium felix-femina	(5,150-5,650)	5,406	(10-360)	4
Ribes lacustre/ Angelica dawsonii	(4,950-5,400)	5,285	(15-360)	5
Menziesia ferruginea/ Epilobium angustifolium	(4,350-5,650)	5,228	(18-270)	19
Menziesia ferruginea/ Cymnocarpium dryopteris	(4,625-6,200)	5,280	(10-360)	23

GRIZZLY BEAR FOOD RESOURCES IN THE FLOOD PLAINS AND AVALANCHE CHUTES OF THE BOB MARSHALL WILDERNESS, MONTANA

Richard D. Mace and Gael N. Bissell

ABSTRACT: The vegetative composition of avalanche chutes and flood plains was investigated in the Bob Marshall Wilderness. Within these two components, 14 distinct vegetation types (VT) were identified, described, and ranked according to forage value. For herbaceous food items, the riparian Picea flood plain VT and the Alnus spp. avalanche chute VT ranked highest in forage value. For fruit items, the terrestrial Picea (flood plain) and xeric herbaceous fan (avalanche) VT's ranked highest. The sand bar (flood plain) and xeric (avalanche) VT's ranked highest for modified stems.

INTRODUCTION

Flood plains and avalanche chutes comprise two major grizzly bear foraging habitat components in the Northern Continental Divide Ecosystem (Mealey and others 1977; Zager 1980). Results of grizzly bear research in the northern Rocky Mountains have shown grizzly bears utilize these two components of habitat throughout the spring, summer, and autumn (Singer 1978; McLellan 1982).

The vegetative structure and composition of both flood plains and avalanche chutes are exceedingly complex due to the interactions and gradients of moisture, elevation, aspect, slope, soils, and succession. The complexity of these two components confounds predictions of foraging habitat quality. Because such predictions are important to grizzly bear management, we investigated in detail the vegetative structure and composition of flood plain and avalanche chute complexes. This project was part of an effort to evaluate grizzly bear habitat in the Bob Marshall Wilderness (Mace 1984 and this volume). The specific objectives of this project were (1) to describe in detail the vegetative composition of the major vegetation types within flood plains and avalanche chute components in the southern Bob Marshall Wilderness; (2) to evaluate the grizzly bear food resource within each vegetation type for three foraging strategies; and (3) to rank vegetation types according to their greatest forage value to the grizzly bear. The results and discussion of the flood plain and avalanche chute components are provided separately.

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STUDY AREA DESCRIPTION

The study area is located in the southern portion of the Bob Marshall Wilderness and comprises 40 400 ha (fig. 1). The region is dominated by rugged mountain topography and dissected by numerous streams and one major river system, the South Fork of the Flathead River. The principal drainages include Gordon, Babcock, and Youngs Creeks, which flow westerly into the South Fork.

The vegetation of the region is strongly influenced by the Pacific maritime climate (Daubenmire 1969). As major Pacific air masses move through the region, much of the precipitation (rain and snow) is deposited on or near the Swan Mountain range (west boundary of the study area); however, in the southern Bob Marshall, some of this precipitation is lost to the Mission Mountain range. As a result, the southern Bob Marshall appears drier than northern portions. The distribution of avalanche chutes is also associated with moisture deposition patterns; most avalanche chutes in the study area are located close to the Swan Divide. The primary forest habitat types (h.t.) of the study area are within the spruce (Picea spp.), Douglas-fir (Pseudotsuga menziesii), and subalpine fir (Abies lasiocarpa) series (Pfister and others 1977). Stands of subalpine larch (Larix lyallii) are found above 2 000 m.

METHODS

Field Procedures

Field work was conducted from June through September of 1982 and 1983. Following reconnaisance efforts, major vegetation types of the flood plains and avalanche tracts were delineated based on dominant plant species and vegetation structural characteristics. Vegetation types were subdivisions of the total habitat component flora and were distinguished by obvious spatial arrangements, physiognomic characteristics, and the existing composition of the vegetation.

Following this stratification, plots were placed randomly within each of these vegetation types.

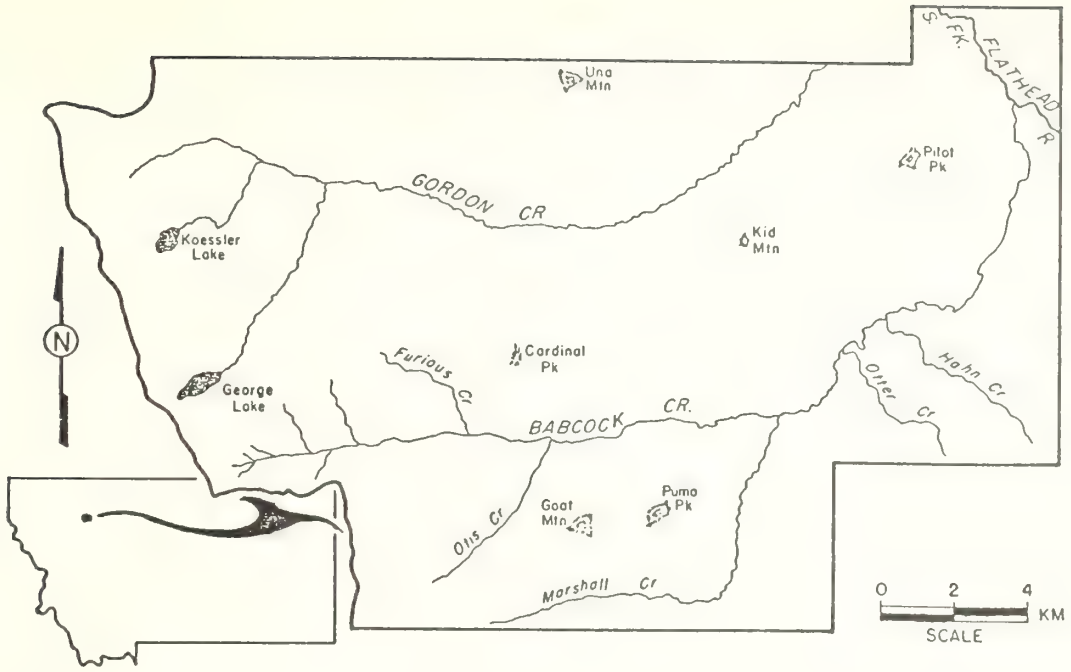


Figure 1.--The study area.

Flood plains were sampled using 375-m^2 (or 1/10-acre) circular plots; avalanche tracts were sampled using 5-m^2 circular plots. The larger plots were selected for the flood plain because this component included timbered vegetation types.

The number of plots taken in each vegetation type was determined by constructing a species-area-curve (Mueller-Dumbois and Ellenberg 1974). Sampling was completed when no new taxa were encountered after three consecutive plots were taken. Complete taxa lists were compiled, although grasses and sedges were combined. Cover values for taxa, nonvascular material, and unvegetated portions were ocularly estimated using the modified Daubenmire cover classes of Pfister and others (1977): 0=absent; T=trace-1 percent; A=1-5 percent; B=5-25 percent; C=25-50 percent; D=50-75 percent; E=75-95 percent; F=95-100 percent. For all plots, tree, shrub, and herbaceous cover per stratum (0-0.9 m; 0.9-2 m; >2 m) were recorded.

Botanical nomenclature followed Hitchcock and Cronquist (1973). Timbered sites were keyed to the appropriate forest habitat type of Pfister and others (1977).

Analytical Procedures

Plant specimens were verified by Peter Stickney (Intermountain Research Station, Missoula, MT). Vegetation data were then assembled into association tables to scrutinize relationships among plots (Mueller-Dombois and Ellenberg 1974). Plot data were entered into a DEC-20 computer to calculate species percent occurrence and average and relative percent covers. Using SP55 programs (Nie and others 1975).

Average percent cover was derived by summing the cover class midpoints for each species and then dividing the summation by total number of plots in the vegetation type. This value was then converted to relative percent cover by converting the total vegetative and nonvegetative covers to 100 percent. The percent occurrence values were also determined for each taxa.

A list of major food plants in the study area was collated using recent literature on grizzly bear food habits from the Northern Rocky Mountains of the United States and southern British Columbia, Canada (Russell and others 1979; Aune and Stivers 1982; Craighead and others 1982; Sumner and Craighead 1973; Mace and Jonkel in press). Food items were placed into one of three major food categories; succulent vegetation, modified stems (roots, bulbs, or corms), or fruit. Each food item was given a seasonal preference rank of 1, 2, or 3, with 3 as high level of use and 1 as low, based on levels of use indicated in the aforementioned studies (table 1).

To quantitatively compare the overall foraging value of the major vegetation types with one another (within both flood plain and avalanche chute components), importance values were calculated using the absolute percent cover of certain bear food items and the preference ranks. First, a "food item importance value" was obtained for each sample plot by multiplying the midpoint of the coverage class for each food item times the food item preference rank. Second, a "vegetation type importance value" was obtained by summing the food item importance values for each plot and then dividing by the total number of plots to obtain the average vegetation type importance value.

Table 1.--Grizzly bear food items and preference ranks used in determining vegetation type importance values

Species	Preference value: Herbaceous	Modified stems	Fruit
FORBS:			
Achillea millefolium	1	2	
Allium cernuum		2	
Allium schoenprasum		2	
Allium spp.			
Angelica arguta	3		
Aster conspicuus	1		
Aster foliaceus	1		
Aster occidentalis	1		
Aster spp.	1	2	
Astragalus alpinus		2	
Astragalus bourgovii		2	
Astragalus robbinsii		2	
Astragalus spp.			
Castilleja spp.	1		
Cirsium spp.	2	3	
Claytonia lanceolata			
Equisetum arvense	3		
Equisetum spp.	3	3	
Erythronium grandiflorum			
Fragaria virginiana	3		
Hedysarum occidentale		2	
Heracleum lanatum	3		
Ligusticum canbyi	2		
Ligusticum spp.	2	1	
Lomatium dissectum		3	
Lomatium cous		3	
Lomatium macrophyllum		3	
Lomatium sandbergii		3	
Lomatium spp.			
Osmorhiza chilensis	3		
Osmorhiza purpurea	3		
Osmorhiza occidentalis	3		
Osmorhiza spp.	3	3	
Oxytropis campestris		2	
Polygomum bistortoides			
Senecio triangularis	2		
Trifolium spp.	3		
Taraxacum spp.	3		
Valeriana sitchensis	2		
Valeriana occidentalis	2		
Veratrum viride	2		
SHRUBS:			
Amelanchier alnifolia			3
Arctostaphylos uva-ursi			2
Cornus stolonifera			2
Prunus virginiana			2
Rhamnus alnifolia			2
Ribes lacustre			1
Ribes viscosissimum			1
Ribes inerme			1
Ribes hudsonianum			1
Ribes spp.			1
Rosa acicularis			1
Rosa woodsii			1
Rosa spp.			1
Rubus idaeus			1
Rubus spp.			1
Shepherdia canadensis			3
Sorbus scopulina			3
Vaccinium scoparium			2
Vaccinium caespitosum			2
Vaccinium globulare			3

Analyses were accomplished for three foraging categories: herbaceous, modified stems, and fruits. Vegetation type importance values were then ranked on an ordinal scale for each foragin strategy. To compare the similarity between vegetation types sampled from different avalanch tracts, coefficients of percent species similari (Jaccard 1912) were calculated. These similarit coefficients were calculated excluding ephemeral taxa because not all areas were sampled at the same time of year nor within the same year. The coefficients were also calculated using only grizzly bear foods. Genera and species of a giv genera were considered different taxa in these analyses. The following formula was used for percent taxa similarity:

$$= \frac{\text{Number of taxa common to both locations (A and}}{\text{Number of taxa unique to location A + number o taxa unique to B + number of taxa common to bo locations}}$$

RESULTS

Description of Flood Plain Vegetation Types

To comply with other classification systems for valley bottom lands, the flood plains of the stu area were divided into two distinct zones (U.S. Department of Agriculture 1978; Pfister and Batchelor 1984). The riparian zone was adjacent to the river channel and susceptible to annual a periodic inundation. The terrestrial zone was that area of terraced valley floor not subjected to flood waters. The terrestrial zone corresponded to relatively flat benches on older alluvium above the riparian zone. Vegetation composition in both zones reflected water table depth, frequency of flood and natural fires, subtle gradients of elevation and temperature, a soil type and depositional pattern. Illustratio of several flood plain vegetation types are presented in figures 2 to 4.

Riparian Zone.--Six vegetation types were identified for the riparian zone of major flood plains. These types represented distinctive ser in the successional pattern on the zone. Each vegetation type was further stratified by its apparent position in the successional process: pioneer, early successional, midsuccessional, la successional, and climax (stable) in convention with Allen (1980).

1. Gravel Bar VT: The gravel bar VT represented the earliest pioneer sere and occupied that portion of the riparian zone directly adjacent t the water channel. Therefore, this vegetation type was inundated during annual spring runoff. Fluvial-deposited pebbles, gravels (approximatel 8 inches), and silts supported 30 taxa. Gravel and silt constituted 86 percent of the cover. Dominant taxa were willow (Salix spp.), common willow-weed (Epilobium glandulosum), clover (Trifolium spp.), and purple milk-vetch (Astragalus alpinus) (table 2).

Table 2.--Relative percent cover and occurrence (percent cover/percent occurrence) of dominant taxa within eight flood plain vegetation types

Taxa	Gravel bar	Sand bar	Salix flat	Mesic herbaceous meadow	Riparian Picea	P. tricho-carpa	Terrestrial spruce	Xeric gram-inoid meadow
FORBS:								
Trifolium spp.	[1]t/44	2/15			4/41			
Epilobium latifolium	5/70							
Senecio pseudaureus		1/85	3/62					
Achillia millefolium		1/100				1/100		
Lupinus spp.		2/54					t/44	
Oxytropis campestris		2/46						
Equisetum spp.			5/46	1/77	2/59	t/25		
Heracleum lanatum		t/7	5/73	2/62	1/63			
Fragaria virginiana		1/65	3/85	6/82		3/75		
Thalictrum occidentale				17/85	11/63			
Smilacena stellata				1/92				
Angelica arguta				1/92	t/56	t/25		
Galium triflorum					3/74			
Epilobium spp.						4/75		
Taraxacum spp.						2/25		
Astragalus miser						1/75		
Epilobium angustifolium							1/65	
Erigeron spp.							1/65	
Eriogonum umbellatum								1/50
Geum triflorum								1/55
Penstemon spp.								3/85
Potentilla spp.								2/45
SHRUBS:								
Rosa spp.		3/62	1/77	8/100	2/81		t/4	
Arctostaphylos uva-ursi			2/31			30/50	29/91	
Salix spp.	2/37		42/85	t/23				
Ribes spp.			5/81	1/54	t/26	t/25		
Lonicera involucrata			4/85	2/77	2/74			
Linnaea borealis							t/13	
Cornus stolonifera				2/15	2/52	42/75		
Vaccinium caespitosum							41/91	
Artemisia tridentata								2/20
GRAMINEAE/CYPERACEAE	3/74	11/69	43/100	41/100	15/100	30/75	7/100	26/100
NONVASCULAR COVER	86/100	51/100	1/74	5/54	15/100	25/100	2/13	41/100

[1]t = < 0.5 percent cover.



Figure 2.--Panoramic view of the Youngs Creek flood plain showing the mesic riparian zone adjacent to the river channel and the upland terrestrial zone along the benches.

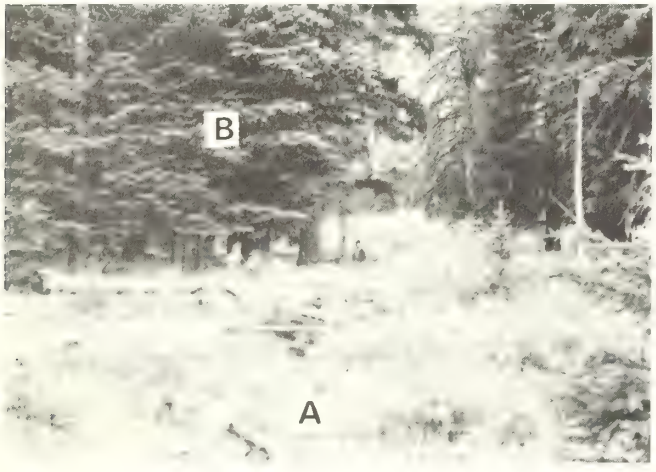


Figure 3.--Mesic herbaceous meadow (A) and riparian Picea (B) VT's within the riparian zone of the flood plain complex.



Figure 4.--Sandbar (A) and Salix spp. flat (B) VT's within the riparian zone of the flood plain complex.

Several "key" herbaceous foods occurred in this vegetation type but were of trace coverage (table Foods present in this type of the modified stem category included purple milk-vetch, wild onion (Allium spp.), and slender crazyweed (Oxytropus campestris). Key fruit-bearing taxa were absent in the type.

2. Sand Bar VT. The sand bar VT occurred on fine-grained fluvial sand and silt deposits. This type, although also considered a pioneer sere, was more stable than gravel bars and would only be disrupted by catastrophic floods. Nonvascular cover was 51 percent. Dominant herbaceous taxa of this vegetation type included slender crazyweed, wormleaf stonecrop (Sedum stenopetalum), lupine (Lupinus spp.), and yellow buckwheat (Eriogonum flavum) (table 2).

Twelve key grizzly bear foods occurred in the vegetation type, all of which were of low cover and occurrence. Modified stems such as slender crazyweed, wild onion, and purple milk-vetch were the only conspicuous foods. Grass and sedge cover was 11 percent.

3. Salix spp. Flat VT. Shrubfields dominated by willow occupied mesic and hydric river oxbows, narrow margins and adjacent to river channels, and to a lesser extent mesic openings in spruce stands. Thirteen shrub taxa were found in this early successional vegetation type. Willow showed the greatest cover in all strata (42 percent). Black twin-berry (Lonicera involucrata) and currant (Ribes spp.) were considered codominant with willow in the lower stratum. The dominant herbs (table 2) were cow-parsnip (Heracleum lanatum), horsetail (Equisetum spp.), and streambank butterweed (Senecio pseudaureus). Several grizzly bear food plants exhibited relatively high cover values in willow flats: cow-parsnip, horsetail, and grasses/sedges (Gramineae/Cyperaceae) (table 3).

4. Mesic Herbaceous Meadow VT. Mesic meadows of the riparian zone were complex mosaics of openings and edges within and between spruce, willow, and lodgepole pine (Pinus contorta) vegetation. On certain sites, these meadows formed abrupt edges between two or more vegetation types, but on other sites formed a gradual continuum from the adjacent type. Apparently favorable combinations of light, moisture, and temperature led to a high diversity of plant taxa. Grasses (primarily bluejoint reedgrass [Calamagrostis canadensis]) and sedges had a combined cover of 41 percent. Western meadowrue (Thalictrum occidentale) was the dominant herbaceous species. Other dominant herbs were strawberry (Fragaria spp.), cow-parsnip, and mountain arnica (Arnica latifolia). Eighteen shrub taxa were recorded in this type, of which red-osier dogwood (Cornus stolonifera) and rose (Rosa spp.) exhibited the greatest cover values (table 2).

Eleven herbaceous food plants occurred in the mesic herbaceous meadow VT (table 3). Cow-parsnip, horsetail, and angelica (Angelica arguta) were key food items of relatively high

Table 3.--Relative percent cover and occurrence (percent cover/percent occurrence) of major bear food items in each vegetation type of the flood plain complex

Taxa	Gravel bar	Sand bar	Salix spp. flat	Mesic herb-aceous meadow	P. tricho-carpa	Riparian spruce	Terrestrial Picea	Xeric gram-inoid meadow
HERBACEOUS								
Heracleum lanatum		[1]t/7	5/73	2/62	t/25	1/63		
Angelica arguta			t/65	1/92	t/25	t/56		
Ligusticum canbyi			t/4					
Osmorhiza occidentalis			t/8	t/15				
Equisetum spp.	t/15		5/46	1/77	t/25	2/59		
Gramineae/Cyperaceae	3/74	11/69	43/100	41/100	30/75	15/100	7/100	20/100
MODIFIED STEMS								
Astragalus spp.	t/26	t/19	t/27	t/23	1/75	t/7	t/4	
Oxytropus spp.	t/4	2/40						
Allium spp.	t/4	t/54	t/15	1/31	t/50	t/15	t/13	t/5
Lomatium spp.		t/8						
FRUITS								
Amelanchier alnifolia			t/4	t/8			t/17	
Vaccinium caespitosum							41/91	
Rosa spp.	t/4	3/62	1/77	8/100	1/100	2/81	t/4	t/5
Ribes spp.		t/15	5/81	1/54	t/25	t/26		
Sheperdia canadensis			t/4	1/23	2/75	t/15	9/13	
Cornus stolonifera				2/15	42/75	2/52		

[1]t = < 0.5 percent cover.

cover and occurrence. Red-osier dogwood and species of rose (Rosa spp.) were dominant fruit-bearing taxa.

5. Populus trichocarpa VT. Small (<1.6 ha) stands of black cottonwood (P. trichocarpa) colonized fluvial sand and gravel deposits of the riparian zone. This midsuccessional type, which was sampled just south of Big Prairie, appeared to have been heavily grazed and trampled by domestic livestock. The overstory canopy was a relatively equal mixture of black cottonwood, Douglas-fir, and lodgepole pine. Clover, dandelion (Taraxacum spp.), strawberry, and Missouri goldenrod (Solidago missouriensis) were dominant herbs. Shrubs with the highest cover and occurrence values included red-osier dogwood, kinnikinnick (Arctostaphylos uva-ursi), and buffalo-berry (Shepherdia canadensis) (table 3).

6. Riparian Picea VT. Three habitat types of the spruce series (Pfister and others 1977) were combined because of similar vegetative qualities. Habitat types within this riparian Picea VT included spruce/sweet-scented bedstraw (Galium triflorum); spruce/queen's cup (Clintonia uniflora) with queen's cup absent, bunchberry (Cornus canadensis) present; and spruce/starry false Solomon's seal (Smilacina stellata). These habitat types existed as small pockets on poorly drained soils of channel oxbows, and have survived nearly two centuries of natural fire (average stand age of 179 years).

Seventy plant taxa were encountered in plots. Dominant taxa, although variable by habitat type, included western meadowrue, streambank butterweed, showy aster (Aster conspicuous), bunchberry (Pyrola spp.), and western twinflower (Linnaea borealis). Alder (Alnus spp.), black twin-berry, and red-osier dogwood were dominant shrubs (table 2). The cover and occurrence of bear food items is given in table 2.

Terrestrial Zone.--Flood plain benches displayed much less vegetation type diversity than the riparian zone. Two vegetation types were sampled in this zone.

1. Terrestrial Picea VT. Seral, well-drained phases of the spruce climax series existed as large, relatively homogeneous stands on flat benches above the riparian zone. All stands sampled were renewed following the wildfire of 1926 and corresponded to the spruce/dwarf huckleberry (Vaccinium ceaspitosum) h.t. Lodgepole pine was the dominant conifer in all strata. Spruce and Douglas-fir stems were present as regeneration in lower strata.

Thirty-five taxa were in sample plots. Dominant shrubs were dwarf huckleberry, kinnikinnick, and buffalo-berry. All herbaceous taxa displayed trace cover values; however, those with the greatest percent occurrence were fireweed lousewort (Pedicularis spp.), fleabane (Erigeron spp.), and lupine (table 2). Herbaceous and

modified-stem bear food items were relatively rare in this type. Buffalo-berry and dwarf huckleberry were important fruit-bearing food items (table 2).

2. Xeric Graminoid Meadow VT. Dry meadows of the terrestrial zone were located on large alluvial fans or existed as small openings within the spruce/dwarf huckleberry h.t. This vegetation type exhibited a pronounced seasonal change, from a late spring/early summer flush to severe desiccation by August.

The xeric meadow VT corresponded to the rough fescue-Richardson's needlegrass (Festuca scabrella-Stipa richardsonii) community type of Johnson (1982) and the rough fescue-Idaho fescue (F. idahoensis) grassland h.t. of Mueggler and Stuart (1980). The big sagebrush (Artemisia tridentata) phase of the aforementioned community type was observed on the Hahn Creek alluvial fan.

Grasses and sedges showed a combined relative cover of 26 percent and occurred in all plots. Dominant herbaceous taxa were sulfur buckwheat (Eriogonum unbellatum), prairiesmoke avens (Geum triflorum), clover, and lupine. Nonvascular ground cover was 41 percent (table 2).

Ranking of Vegetation Type Importance Values by Forage Categories

Herbaceous Forage Category.--Calculations of vegetation type importance values (IV's) for the herbaceous foraging season yielded values from 1 to 54 for eight flood plain vegetation types (table 4). Riparian zone vegetation types generally ranked higher in succulent grizzly foods than did those of the terrestrial zone. The riparian Picea VT, a timbered sere, ranked highest of all flood plain types. Openings in the riparian spruce canopy, the mesic herbaceous meadow VT, ranked second. The terrestrial zone (flood plain bench) was negligible in succulent bear foods.

Plants whose underground parts are eaten by grizzly bears were found in all vegetation types, but were of low cover and occurrence. The sand bar VT ranked highest of all types due to the presence of milk-vetch and slender crazyweed. Interestingly, yellow hedysarum (Hedysarum sulphurescens), whose roots are extensively eaten in the North Fork of the Flathead River (Singer 1978; McLellan 1982), was observed only once in the flood plain component.

Fruit Forage Category.--The terrestrial Picea VT ranked highest of all flood plain types for fruit-bearing shrubs preferred by grizzly bears (table 4). Buffalo-berry and dwarf huckleberry were the primary foods in this type and were of lower cover elsewhere in the flood plain. Buffalo-berry appeared to produce the greatest number of berries in open-timbered stands growing on rocky alluvium. Conversely, dwarf huckleberry stems were more prevalent in highly stocked lodgepole stands and exhibited poor fruit production during the two years of field investigation. Interestingly, this terrestrial Picea VT ranked second of all vegetation types in the temperate, subalpine zones of the study area (Mace, this volume).

Mesic herbaceous meadows and the black cottonwood stands ranked second during the fruit forage season. Red-osier dogwood, buffalo-berry, and species of currant were primary foods in these vegetation types. The remaining five vegetation types of the flood plain complex ranked low for this season.

Avalanche Chutes

Seven avalanche chutes were sampled from various dominant aspects (table 5). Six major vegetation types were distinguished in avalanche chutes: (1) streamside; (2) Alnus spp. shrubfields; (3) Xerophyllum tenax; (4) xeric; (5) mesic herbaceous fan; and (6) xeric herbaceous fan. Several of these vegetation types are illustrated in figures 5 to 7.

Description of Vegetation Types

1. Streamside VT. The streamside VT occurred adjacent to the intermittent and continuously flowing streams of five sampled avalanche tracts. Marshall Creek (north-facing) and Otis Creek (south-facing) did not have streamside VT types. Plots in the streamside VT did not include dense alder shrubfields (described below), although they did include randomly encountered individual shrubs. For all avalanche chutes containing this vegetation type, the streamside VT occupied the least area, ranging from 2 to 8 percent of the entire avalanche chute (table 5).

Dominant herbaceous taxa included arrowleaf groundsel (Senecio triangularis), cow-parsnip, streambank butterweed, and sweet-scented bedstraw (table 6). Lewis' monkey-flower (Mimulus lewisii) and brook saxifrage (Saxifraga arguta) occupied hydric sites. The dominant shrub species in stratum A (0.0-0.9 m) were alderleaf buckthorn (Rhamnus alnifolia), thimbleberry (Rubus parviflorus), and willow.

Important bear food items in this vegetation type included mesic herbaceous forbs such as cow-parsnip, dandelion, arrowleaf groundsel, strawberry, western sweet-cicely (Osmorhiza occidentalis), and licorice-root (Ligusticum spp.) (table 7).

Coefficients of similarity for streamsides varied from 29 to 49 percent when all but ephemeral taxa were included (mean = 37 percent) (table 8). The greatest percent similarity was between the Bigslide and Otter Creek avalanche tracts. When only grizzly bear foods were considered, the average increased to 53 percent (range 28 to 37 percent). The two chutes demonstrating the greatest similarity were Bigslide (east-facing)

Table 4.--Vegetation type importance values and (ranks) for three forage categories (flood plain complex habitat component)[1]

Vegetation type	Forage category		
	Herbaceous	Modified stem	Fruit
Riparian *Picea*	54 (1)	0.5 (4)	5.0 (4)
Mesic herbaceous meadow	36 (2)	2.0 (2)	25.0 (2)
Populus trichocarpa	10 (3)	2.0 (2)	25.0 (2)
Salix flat	6 (4)	1.0 (3)	9.0 (3)
Xeric graminoid meadow	5 (5)	< .1 (6)	< .1 (6)
Sand bar	5 (5)	5.0 (1)	2.0 (5)
Gravel bar	2 (6)	0.5 (4)	< .1 (6)
Terrestrial *Picea*	1 (7)	0.2 (5)	47.0 (1)

[1]Figures in parentheses indicate ordinal ranking scale.

Table 5.--Acreage and relative percent area (acres/percent area) of each vegetation type in seven sampled avalanche tracts

VT	Chute and aspect						
	Marshall, south	Babcock, south	Otis, southeast	Bigslide, east	Otter Creek, west	Jumbo, north	Marshall, north
Streamside	25/3	2/1		5/5	3/7	1/8	
Alnus spp.	15/1	7/3		7/8	1/2	1/8	16/89
Mesic herbaceous fan			6/2		8/17		2/11
Xeric herbaceous fan			6/2		21/45		
X. tenax	488/51	95/42	127/39		3/7		
Xeric	433/45	124/54	182/57	80/87	10/22	6/50	
Burn shrubfield[1]						4/34	
Total	961/100	228/100	321/100	92/100	46/100	12/100	18/100

[1]This VT was not found in any other avalanche tract. The upper part of this chute contained a burned *Abies lasiocarpa*/*Xerophyllum tenax* - *Vaccinium globulare* habitat type (Pfister and others 1977).

Table 6.--Relative percent cover and occurrence (percent cover/percent occurrence) of dominant taxa in six avalanche chute vegetation types

	Vegetation type					
	Xeric n=114	Xeric herbaceous fan n=26	Xerophyllum tenax n=93	Streamside n=129	Alnus shrubfield n=52	Mesic herbaceous fan n=45
FORBS:						
Balsamorhiza sagittata	[1]3/25					
Achillea millefolium	[1]t/8 2	1/91	t/73			2/38
Sedum stenopetalum	t/60					
Antennaria microphylla	1/49					
Galium boreale		5/25				
Fragaria virginiana		6/78	5/63			
Osmorhiza occidentalis		5/38	2/20		1/15	1/36
Aster spp.		10/75				
Solidago canadensis		5/38				
Xerophyllum tenax			45/82			9/36
Erigeron spp.			5/60			
Senecio triangularis				19/70	/75	15/73
Heracleum lanatum				7/47	8/52	4/40
Senecio pseudaureus				6/59		
Galium triflorum				2/24	2/52	
Taraxacum spp.				2/30		
Veratrum viride					/54	
Thalictrum occidentale			1/35		/50	5/78
Streptopus amplexifolius					1/42	
SHRUBS:						
Amelanchier alnifolia	5/51		1/26			
Rhamnus alnifolia		18/28				
Symphoricarpos albus		5/16				
Vaccinium scoparium			4/21			
Vaccinium globulare			1/11			
Alnus spp. (0.9-2.0 m)					40/89	
Alnus spp. (>2.0 m)				4/15	38/71	
Sorbus spp. (0.9-2.0 m)					3/17	
Salix spp. (0.9-2.0 m)				3/15		
Ribes lacustre						5/22
GRAMINEAE/CYPERACEAE	30/100	21/100	8/60	8/100	/72	26/100
NONVASCULAR COVER	45/100	2/100	20/100	9/100	/100	12/100

[1]t = <0.5 percent cover.

Table 7.--Relative percent cover and occurrence (percent cover/percent occurrence) of major bear food items in avalanche chute vegetation types

	Vegetation type					
Taxa	Streamside	Alnus spp.	Mesic herbaceous fan	Xeric herbaceous fan	X. tenax	Xeric
HERBACEOUS						
Heracleum lanatum	7/47	8/52	4/40	t/9	t/3	
Angelica arguta	[1]3/43	1/10	1/18	t/9	t/5	
Ligusticum canbyi	t/8	1/14				
Osmorhiza occidentalis		1/15	1/36	5/38	2/20	t/8
Taraxacum spp.	2/30					
MODIFIED STEMS						
Aster spp.				10/75	t/4	t/5
Erythronium grandiflorum	t/6				t/12	t/2
Hedysarum occidentale			t/2		1/28	
Lomatium spp.	t/2		t/4		t/5	t/27
FRUITS						
Sorbus scopulina	3/17	1/8	t/2		1/6	t/1
Vaccinium caespitosum		t/2	t/2		4/21	t/3
Vaccinium scoparium		t/2	t/2		4/21	t/3
Ribes spp.	t/22	3/10	5/22			
Amelanchier alnifolia					1/26	5/51

[1]t = <0.5 percent cover.

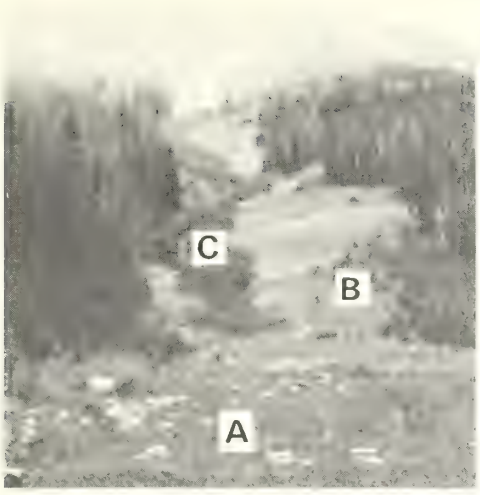


Figure 5.--Mesic herbaceous fan (A), xeric (B), and Alnus spp. (C) VT's of the avalanche chute complex (Otter Creek).



Figure 6.--An extensive area of the Alnus spp. VT of the avalanche chute complex (near Koessler Lake).



Figure 7.--The Xerophyllum tenax VT of the avalanche chute complex (Otis Creek).

and Babcock (south-facing). Only three of 113 taxa were common to all streamsides: western meadowrue, cow-parsnip, and arrowleaf groundsel.

2. Alnus spp. VT. Shrubfields dominated by mountain alder were found on cool and moist sites in all but the south-facing chutes in Marshall and Otis Creeks. North-facing and east-facing portions of avalanche chutes tended to support the most extensive alder stands. In south-facing chutes, alder shrubfields generally were restricted to streamside areas. The Alnus spp. VT usually occupied a low percent area of the avalanche complexes (table 5).

The dominant shrub over 0.9 m was alder; however, 11 other shrubs did occur in this vegetation type. The most common species included willow, fool's huckleberry (Menziesia ferruginea), black twin-berry, and alderleaf buckthorn. Common herbaceous species included American false hellebore (Veratrum viride), arrowleaf groundsel, and western meadowrue (table 6). Mesic herbaceous bear food items such as cow-parsnip, sharptooth angelica, licorice-root, and western sweet-cicely were also common under the canopies of alder and along the shrub ecotones.

The average of 10 similarity coefficients using all taxa was 37 percent. When only bear foods were evaluated, the coefficient increased to 39 percent. The greatest similarity among chutes was 50 percent (table 8).

3. Mesic herbaceous fan. The lower portions of cool and moist aspect avalanche chutes frequently supported mesic herbaceous and graminoid vegetation. Because of the northerly to northwesterly aspect and/or upper elevational position of these chutes, these fans held snow longer than other chutes and exhibited delayed phenological development. Mesic herbaceous fans were found in the west-facing Otter Creek, southeast-facing Otis Creek, and the north-facing Marshall Creek avalanche chutes.

Arrowleaf groundsel, beargrass (Xerophyllum tenax), western meadowrue, and cow-parsnip were dominant herbs (table 6). Grasses and sedges showed a combined coverage of 19 percent and appeared in all sample plots. Nonvascular ground comprised 9 percent cover. Occasional stems of subalpine fir (Abies lasiocarpa), Douglas-fir, and spruce were present.

Key bear foods were much the same as those mesic herbaceous species found in the streamside and Alnus spp. VT's (table 7).

4. Xeric herbaceous fan. The vegetation of several avalanche fans was greatly influenced by surface and subsurface ephemeral stream runoff. On exceedingly convex and generally warm-aspect fans, combinations of taxa slowly graduated from mesic conditions associated with the streamside toward drier conditions near the edges. One example of this drier fan type was at Bigslide.

Table 8.--Individual and average Jaccard percent similarity coefficients for vegetation types of the avalanche chute habitat component (all but ephemeral taxa/grizzly bear foods only)

Streamside VT (n=129)

	Marshall Cr. S. facing n=31	Bigslide E. facing n=26	Otter Cr. W. facing n=23	Babcock Cr. S. facing n=29	Jumbo Cr. N. facing n=20	Otis Cr. SW. facing	Marshall Cr. N. facing	Averages
Marshall Cr.		38/38	34/61	44/70	33/55	Absent	Absent	37/53
Bigslide			49/47	38/75	29/28			
Otter Cr.				31/63	37/54			
Babcock Cr.					34/41			

Alnus Shrubfield VT (N=52)

	Jumbo Cr. N. facing n=8	Bigslide E. facing n=12	Otter Cr. W. facing n=10	Babcock Cr. S. facing n=12	Marshall Cr. N. facing n=10	Otis Cr. SW. facing	Marshall Cr. S. facing	Averages
Jumbo Cr.		40/21	35/50	36/27	27/33	Absent	Absent	37/32
Bigslide			30/36	41/32	33/19			
Otter Cr.				27/22	48/50			
Babcock Cr.					48/27			

Xerophyllum tenax VT (n=93)

	Babcock Cr. S. facing n=55	Bigslide E. facing n=12	Marshall Cr. S. facing n=20	Otis Cr. SW. facing n=6	Otter Cr. W. facing	Jumbo Cr. N. facing	Marshall Cr. N. facing	Averages
Babcock Cr.		28/38	25/33	25/39	Absent	Absent	Absent	32/36
Bigslide			27/18	50/45				
Marshall Cr.				38/40				

Xeric, warm aspect VT (n=114)

	Marshall Cr. S. facing n=34	Bigslide E. facing n=18	Otter Cr. W. facing n=36	Babcock Cr. S. facing n=20	Otis Cr. SW. facing n=6	Marshall Cr. N. facing	Jumbo Cr. N. facing	Averages
Marshall Cr.		45/60	37/43	38/36	33/45	Absent	Absent	34/39
Bigslide			32/21	31/50	28/20			
Otter Cr.				29/29	35/40			
Babcock Cr.					32/45			

Alderleaf buckthorn was the dominant species at sites of high moisture with cow-parsnip, western meadowrue, sharptooth angelica, western sweet-cicely, and blue stickweed (Hackelia jessicae) present beneath the shrub canopy. Wild strawberry, northern bedstraw (Galium boreale), asters, fleabane, sulfur buckwheat, and sticky purple geranium (Geranium viscosissimum) occupied the drier sites. Snowberry (Symphoricarpos albus) and swamp gooseberry (Ribes lacustre) were dry site shrubs.

5. Xerophyllum tenax VT. Vegetation dominated by beargrass varied greatly in areal extent among avalanche chutes. It occupied as much as 50 percent of Marshall Creek's south-facing chute to only 11 to 12 percent of the Otter and Babcock avalanche complexes (table 5). At the Marshall and Otis Creek locations, this vegetation type dominated much of the upper undulating portions as well as the low fanlike areas at the bottoms of the chutes. The Xerophyllum tenax VT was found in all but the north-facing Marshall Creek and west-facing Otter Creek avalanche chutes. Beargrass showed the greatest herbaceous cover value with strawberry, fleabane, western sweet-cicely, and western meadowrue also exhibiting relatively high coverages. Grouse whortleberry (Vaccinium scoparium) was the dominant shrub under 0.9 m. Cover of globe huckleberry (Vaccinium globulare) was the greatest in burned areas. Nonvascular ground had a cover value of 20 percent. Combined, grasses and sedges showed 8 percent cover.

Certain upper-elevation portions of sampled avalanches had been subjected to ground fires within the last 50 years (Babcock and Jumbo Creeks). The most obvious influence of fire on these sites was an increase in shrub presence and cover values. For example, the upper elevation Xerophyllum tenax VT of the Babcock Creek chute (burned 1934) showed twice the number of shrub taxa compared to other similar sites. Due to fire influences, similarity coefficients were low (table 8). Principal bear foods of the Xerophyllum tenax VT included the berry-producing shrub species (particularly where fires had occurred) and grasses and sedges. Other species included such forbs as yarrow (Achillea millefolium), wild strawberry, Indian paintbrush (Castilleja spp.), valerian (Valeriana spp.), and modified stems such as western hedysarum.

Similarity coefficients among vegetation types sampled from four avalanche chutes ranged from 28 to 45 percent when ephemeral taxa were excluded. When considering bear food items only, the similarity coefficients ranged from 21 to 60 percent similarity.

6. Xeric VT. The xeric VT occurred on steep, thin, and well-drained soils in all but the north-facing avalanche chutes. This vegetation type frequently occupied linear bands along the south-facing aspects of the concave avalanche chutes. In the more expansive chutes, the xeric VT was intermixed with the Xerophyllum tenax VT. Where this vegetation type occurred, it occupied more than 40 percent of the avalanche chute (table 5).

Dominant species in the xeric VT included arrowleaf balsamroot (Balsamorhiza sagittata), yarrow, and wormleaf stonecrop. Among shrubs, serviceberry (Amelanchier alnifolia) showed the greatest cover. Grasses, principally Idaho fescue, bluebunch wheatgrass (Agropyron spicatum), showy oniongrass (Melica spectabilis), and sedges had a combined cover of 25 percent. Nonvascular ground cover constituted 32 percent. Except for grasses and sedges, bear food items were not particularly common in this vegetation type. Most notable were modified stems such as wild onion and several species of biscuit-root (Lomatium spp.).

Similarity coefficients derived from five sampled xeric VT's averaged 35 percent for all but ephemeral taxa. When only grizzly bear foods were considered, the similarity increased to 39 percent (table 8).

Ranking of Vegetation Type Importance Values by Forage Category

Herbaceous Forage Category.--For the herbaceous foraging strategy, the highest ranking vegetation type was the Alnus spp. VT (IV = 61) followed by the mesic herbaceous fan, streamside, and xeric herbaceous fan (table 9). The Xerophyllum tenax VT was ranked fourth (IV = 27), and the xeric VT ranked lowest (table 9).

Modified Stems Forage Category.--Importance values for modified stems were relatively low (table 9). The X. tenax VT ranked the highest (IV = 5) due to the occurrence of western hedysarum, milk-vetch (Astragulus spp.), and glacier-lily (Erythronium spp.). The xeric VT ranked second highest and contained digging food items such as wild onion, milk-vetch, fern-leaved and Sandberg's biscuit-root (Lomatium dissectum and L. sandbergii), and glacier-lily.

Fruit Forage Category.--Most avalanche vegetation types exhibited low fall foraging season values because of a general lack of berry-producing shrubs in the nontimbered portions of the tracts. The xeric herbaceous fan VT scored the highest value for the fall foraging season (IV = 26) due to the presence of shrub species such as serviceberry and alderleaf buckthorn.

DISCUSSION

To date, very little information on grizzly bear food habits or habitat use exists for the Bob Marshall Wilderness. Therefore, it was assumed, for this investigation, that grizzly bear food habits and habitat selection in the Bob Marshall Wilderness would be similar to those of other grizzly bears studied in northwest Montana. It also was assumed that grizzly bears would select food resources at the vegetation type level rather than at the component level. This was

Table 9.--Vegetation type importance values of six avalanche tract vegetation types for three foraging strategies[1]

Vegetation type	Forage category		
	Herbaceous	Modified stem	Fruit
Alnus spp.	61 (1)	< 0.1 (4)	3 (5)
Mesic fan	40 (2)	< 0.1 (4)	5 (4)
Streamside	37 (3)	0.1 (3)	3 (5)
Xeric fan	32 (4)	< 0.1 (4)	26 (1)
X. tenax	27 (5)	3.0 (1)	9 (2)
Xeric	3 (6)	1.0 (2)	8 (3)

[1]Figures in parentheses indicate ordinal ranking scale.

corroborated by Stelmock (1981), who stated that:

> [Grizzly bear] habitat use during summer was mainly confined to very specific vegetation types which provided dense cover of favored plant foods. Habitat use patterns closely followed the seasonal variations in quantity and quality of important foods.

This investigation focused on assessing the relative foraging importance to grizzly bears of various vegetation types within both avalanche chutes and flood plains. Results indicate that both flood plains and avalanche tracts are composed of a variety of distinguishable vegetation types within which bear food items varied in composition and abundance. In addition to the forage quality of specific vegetation types, it is important to consider the distribution and juxtaposition of these vegetation types as well as their areal extent.

The more mesic vegetation types within avalanche chutes and flood plains clearly provided an abundance of mesic herbaceous bear foods such as cow-parsnip, sawtooth angelica, western sweet-cicely, and others. Often, these vegetation types occupied the least area. For example, in avalanche tracts, the Alnus spp. VT ranked highest for the herbaceous category, but occupied the least area of most chutes sampled.

In avalanche chute VT's, the xeric fan exhibited the highest IV for the fruit category, primarily because of the abundance of alderleaf buckthorn found in the stream area of the fan. In general, fruit-bearing shrubs were not abundant in any of the avalanche vegetation types sampled except where the types had burned (Babcock and Jumbo). Even in the burns, the abundance of fruit-bearing shrubs was not extensive; however, fruit-bearing shrubs such as globe huckleberry were highly abundant in the timbered stringers located within many avalanche tracts and along the timbered edges. These areas were not sampled in the manner of the avalanche chutes and were considered part of the forest habitat types. Results of sampling forested types are reported elsewhere (Mace, this volume). The highest ranking area for fruit-producing shrubs in the flood plain complex was on the benches above the river channel. The diversity of shrub taxa sought by grizzly bears was less on the benches as compared to the riparian zone. However, the high importance value of these areas was attributed to a few, highly favored fruit-bearing shrubs such as buffaloberry

Vegetation types in both the avalanche tracts and flood plains generated relatively low importance values for the modified stem category. It appears that because of the small above-ground size and the ephemeral nature of digging food items, the sampling methods used in this study were not sensitive to this food category. Even other components such as slab rock and alpine meadows, which contain a variety of digging foods, yielded importance values less than 5 (Mace, this volume) The consistency of these habitat descriptions within the study area was evaluated using the Jaccard Similarity coefficient (Jaccard 1912). Results of the similarity coefficients indicated that seasonal forage values should be assessed from many areas and not from a single avalanche tract or portion of a flood plain. Similarity coefficients, using a conservative number of grizzly bear food items, were rarely over 50 percent for each avalanche tract vegetation type sampled from different areas. If one were to only intensively sample one avalanche tract, the descriptions would be less than 50 percent similar in bear food composition in comparison to other chutes in the area.

To look at the extent to which avalanche vegetative descriptions could be extrapolated, avalanche tracts in the northern end of the Bob Marshall wilderness were inspected. Comparisons indicated subtle differences in vegetative compositions and occurrences of certain vegetation types. For example, south-facing avalanche tracts of Trickle and Cannon Creeks in the northern Bob Marshall contained mesic herbaceous meadows which were not found in south-facing avalanches in the southern study area. In addition, plant indicators of relatively moist habitats such as pachistima (Pachistima myrsinites) and queen's cup were observed much more often in the northern Bob Marshall than in the southern study area. Finally, it was noted that the north-facing

avalanche tracts were more abundant and extensive in the northern wilderness drainages than in the southern ones. Based on these observations, extrapolation of vegetation descriptions and values beyond the study area should be done with caution.

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A COMMON SENSE APPROACH TO GRIZZLY BEAR HABITAT EVALUATION

Matthew M. Reid and Steven D. Gehman

ABSTRACT: The common sense approach to evaluating grizzly bear habitat includes three main efforts: (1) collecting and mapping of all known information pertaining to grizzly bear use of an area; (2) on-the-ground reconnaissance and resource sampling (including habitat sampling and mapping, ungulate use surveys, and grizzly bear use surveys); and (3) analysis of data. Ecological and philosophical considerations related to the approach are discussed. Critiques of the Forest Service approach to evaluating grizzly bear habitat in the Clark's Fork Corridor (Shoshone National Forest) and the Mount Hebgen area (Gallatin National Forest) are provided. Special attention is given to Forest Service oversight of critical components of the evaluation process and to the implications of such oversight. The purpose is not to espouse a new methodology, but to remind resource managers that appropriate existing methodologies are frequently overlooked, and that the common sense approach can yield valuable management information if properly conducted. A case study (by Reid Environmental Services) of the proposed evaluation approach to grizzly bear habitat in the Northern Yellowstone Rim area is reviewed. Specific procedures and findings are presented, as are conclusions regarding the applicability of the findings to management of grizzly bear habitat in the Greater Yellowstone Ecosystem. Suggestions for future grizzly bear research efforts in the Greater Yellowstone Ecosystem are presented.

INTRODUCTION

Current delineations of grizzly bear management situations (USDA and USDI 1979) do not accurately reflect grizzly bear use of habitat in many portions of the Greater Yellowstone Ecosystem (GYE). Although the guidelines were intended to define management situations ecologically, many situation boundaries actually reflect political, social, and economic concerns (Hawkes 1976). The purposes of this paper are to review a common sense approach to evaluating grizzly bear habitat in the GYE and to illustrate the applicability and effectiveness of such an approach. We present our methodology and examples of our work in three areas of the Gallatin and Shoshone National Forests, where we determined that delineations of grizzly bear management situations did not reflect grizzly bear use.

The common sense approach to evaluating grizzly bear habitat consists of three main categories of effort: (1) collection and mapping of all known information pertaining to grizzly bear use of an area, (2) on-the-ground reconnaissance and resource sampling, and (3) data analysis.

Collection of pertinent information should include reviews of published literature, agency reports and data, and existing habitat maps and aerial photographs, as well as interviews with agency personnel, researchers, landowners, residents, and users of the area (outfitters, sportsmen, recreationists). Information that should be recorded includes dates, locations, and details of grizzly bear activity in the area and details of habitat alterations (fire, agriculture, logging, development) that have occurred in the area. The product of this phase of work should be a series of map overlays, showing the locations of grizzly bear activity and relevant habitat information.

Habitat sampling and mapping and grizzly bear and ungulate use surveys are critical components that should be conducted during the field work phase of the habitat evaluation process. Appropriate methodologies have been developed for sampling and mapping grizzly bear habitat components in the northern ecosystem (Christensen 1979; Mealey 1977; Mealey and others 1977) and in the Yellowstone Ecosystem (Puchlerz and others 1984). Methods of Puchlerz and others (1984) require determinations of habitat types (Pfister and others 1977), cover types, and nonforest components as the basis for delineating grizzly bear habitat components. We used these methods extensively during our 1984 field season and found them to be appropriate for describing habitat in the northern Yellowstone area. Widespread use of existing methodologies by researchers and resource managers will facilitate uniform documentation, interpretation, and comparison of habitat information.

Thorough surveys of the study area should be conducted during all seasons to document grizzly bear use. Field crews should systematically search for and record observations of bear tracks, scats, day beds, feed sites, and dens. Samples of bear hair should be collected from vegetation, logs, rocks, trails, day beds, and other features for species determinations to be made by a qualified expert. Whenever possible, bear scats should be collected and analyzed to further our knowledge of bear food habits.

If ungulates have been shown to be an important food source for grizzlies, as is the case in the

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Yellowstone Ecosystem (Knight and others 1980), then surveys of ungulate use patterns should be conducted in conjunction with habitat sampling and grizzly bear use surveys. Efforts should include documentation of species and numbers of ungulates observed, availability of ungulate carrion, and seasonal use patterns of ungulates (including general ranges, and concentrated use areas such as elk calving areas and winter and spring transition ranges). Censuses conducted from roads and transects through ungulate ranges are effective means of obtaining ungulate use data. Whenever possible, results of aerial surveys conducted by State and Federal agencies should be obtained to supplement data.

When planning field activities, factors such as timing of efforts, level of effort, and qualifications of personnel should be carefully considered. Timing of field efforts can seriously affect habitat sampling, grizzly bear activity surveys, and ungulate use surveys. Habitat sampling should be coordinated with the area's plant phenology to ensure that indicator species are present. Grizzly bear use surveys should be conducted during all seasons when bears are active. Special searches should be made to locate den sites, evidence of predenning and postdenning activity, and carcass feed sites. Surveys of ungulate use should be conducted year round; however, special attention should be given to early spring and birthing periods when grizzlies are most likely to prey upon vulnerable ungulates. It is impossible to establish specific guidelines for appropriate levels of field activities; however, effort should be expended until experienced personnel feel that samples representative of the area have been obtained during all critical periods of the year. Finally, it is important to have trained personnel conducting the field sampling and surveys. All of these factors contribute to the accuracy and applicability of results obtained from field work.

Data analysis should include compilation of qualitative and quantitative descriptions of habitat and associated use by grizzly bears. Habitat components should be mapped and assigned importance values. Grizzly bear and ungulate use data should be mapped on overlays to aid in visualizing habitat-animal interactions. Several guidelines should be kept in mind when examining results from the habitat evaluation process:

1. Although it may be desirable or necessary to divide an area into smaller units for evaluation, always maintain a broad perspective of grizzly bear requirements and of options available to grizzlies for achieving those requirements; that is, keep in mind the biological characteristics of the animal and ecological relationships that govern the animal's behavior (U.S. Government 1983; Mealey 1977).

2. Consider cumulative impacts to grizzly bears on an ecosystem-wide basis; when considered as small, individual pieces of habitat, few areas are absolutely critical to the survival of grizzly bears in a particular ecosystem; however, the juxtaposition of habitat units and knowledge of the cumulative characteristics of and pressures on those units play a significant role in the value or importance of any one unit.

3. Acknowledge the variable nature of biological and ecological relationships; results from one season or one area are only samples.

FOREST SERVICE EVALUATIONS

Mount Hebgen Area.--Our first example of grizzly bear habitat evaluation in the Greater Yellowstone Ecosystem comes from the Mount Hebgen area of the Gallatin National Forest in southwestern Montana. In 1973, Ski Yellowstone, Inc., applied for a special use permit to develop a winter sports complex at Mount Hebgen. The Ski Yellowstone Corporation then funded a wildlife study in the Mount Hebgen area during spring and summer of 1973 (Haglund 1973). The study consisted of two flights over the study area and an undocumented amount of on-the-ground reconnaissance work. The objective of the study apparently was to evaluate potential impacts of development on wildlife in the Mount Hebgen area. The project report dealt mainly with big game animals (elk and moose) and included one short paragraph about grizzly bears (Haglund 1973). Grizzly bear activity was documented in three drainages near the proposed development site, but not on the primary study area.

The Forest Service, U.S. Department of Agriculture, then issued the special use permit for the Ski Yellowstone development. In response to public opposition to this decision and to concerns about potential impacts to wildlife, particularly grizzly bears, the Ski Yellowstone Corporation funded a second wildlife study near the development site. This study was conducted by Mealey (1976) during late spring and early summer, 1976, and was oriented toward evaluating grizzly bear habitat quality in the Mount Hebgen area. Based on the area's low potential for producing grizzly bear food, Mealey (1976) concluded that the area was low-quality grizzly habitat. Other important factors related to grizzly bear ecology were not considered in this study (Mealey 1977).

In 1977, the Forest Service completed an Environmental Impact Statement (EIS) for development in the Mount Hebgen area. The EIS indicated the preferred alternative was to construct the proposed Ski Yellowstone development. In the EIS, all data concerning potential impacts to wildlife came from the previously mentioned studies of Haglund (1973) and Mealey (1976). Included in the EIS was a Fish and Wildlife Service, U.S. Department of the Interior, biological opinion of "no jeopardy" to the Yellowstone grizzly bear population.

For the next several years, public comments and debate were heard regarding the EIS and the proposed development. Meanwhile, in 1979, the "Guidelines for Management Involving Grizzly Bears in the Greater Yellowstone Area" were published

(USDA and USDI 1979), and efforts to classify grizzly bear habitat according to management situations (MS) began. Although the entire Mount Hebgen area was proposed as critical grizzly bear habitat by the Fish and Wildlife Service in 1976 (USDI 1976), the Forest Service classified the site of the proposed Ski Yellowstone development as MS 2 habitat and land immediately adjacent to the site as MS 1 (USDA and USDI 1979).

In August, 1982, the Forest Service granted a special use permit for the development of the Mount Hebgen area by the Ski Yellowstone Corporation. Concern for grizzly bears and other wildlife resurfaced, and in 1983 several conservation groups asked the Fish and Wildlife Service to review data and reconsider the 1977 biological opinion of "no jeopardy" to grizzly bears. The Fish and Wildlife Service complied with this request and in 1984 reaffirmed the "no jeopardy" opinion (Brewster 1984).

We believe that the Forest Service and Fish and Wildlife Service overlooked several significant factors when they evaluated the Mount Hebgen area as grizzly bear habitat. First, they made little effort to obtain and use information regarding grizzly bear use of the area from residents and users of the area, and from researchers from other agencies. Local residents and users of the area should have been interviewed throughout the evaluation process, and their responses should have been documented in the EIS. Similarly, pertinent information should have been collected from the Interagency Grizzly Bear Study Team (IGBST). The IGBST had been recording grizzly bear sightings in the Mount Hebgen area since 1973 and had been monitoring locations of radio-collared grizzlies in the area since 1975 (Knight and Blanchard 1984); none of the IGBST data appeared in the EIS. The significance of this omission was especially apparent in the 1984 review of data conducted by the Fish and Wildlife Service. By that time, the IGBST had been recording sightings of grizzlies for 10 years and radio-locations of grizzlies for 8 years, and had accumulated a significant amount of data regarding grizzly bear use of the Mount Hebgen area. For example, between 1973 and 1983, 84 sightings of single grizzlies and 15 sightings of females with young were made within 10 miles of Mount Hebgen; between 1975 and 1983, seven radio-collared grizzlies used the Mount Hebgen area (Knight and Blanchard 1984). The distributions of documented sightings and radio-locations of grizzlies (fig. 1) indicate that Mount Hebgen and the surrounding area were heavily used by grizzlies between 1973 and 1983 (Knight and Blanchard 1985) and that management situation delineations did not reflect that use.

During the EIS review process, representatives of the Fish and Wildlife Service, the U.S. Environmental Protection Agency, and the Montana Department of Fish, Wildlife, and Parks all expressed concerns regarding the welfare of grizzly bears and their habitat (USDA 1977); however, none of these concerns was adequately addressed by the Forest Service before the special use permit was granted.

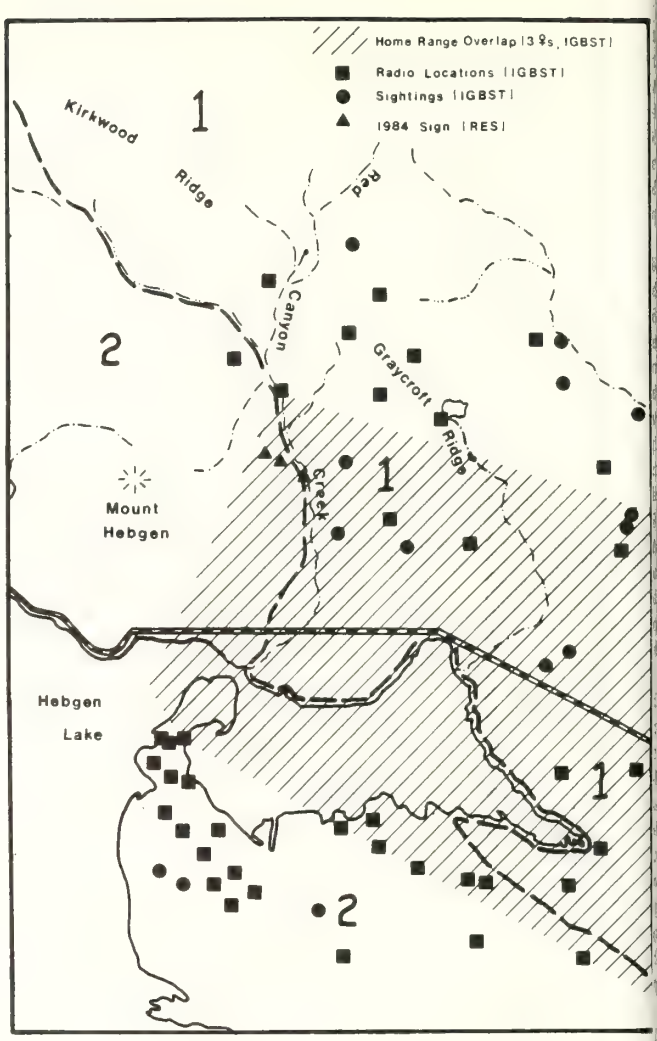


Figure 1.--Distributions of sightings and radio-locations of grizzly bears, 1973-83, in management situations in the Hebgen area, Gallatin National Forest.

A second major problem was inadequate field work and incomplete examination of critical grizzly bear components. The studies of Haglund (1973) and Mealey (1976) were conducted in late spring and early summer, and neither investigator made an intensive search for evidence of grizzly bear activity. Although Haglund (1973) documented big game distributions and Mealey (1976) studied grizzly bear food production, neither investigator examined the potential for ungulates as a major grizzly bear food source in the Hebgen area. Intensive surveys of grizzly bear and ungulate activity should be conducted throughout the portion of the year that grizzly bears are active (approximately April through October).

We visited Mount Hebgen in June 1984 while participating in a Forest Service grizzly bear habitat mapping workshop. During the approximately 4 hours that we spent mapping habitat components on Mount Hebgen, we discovered two

ites where grizzlies had recently fed upon elk, hree grizzly bear day beds, three bear scats, and wo sets of grizzly bear tracks (Reid 1984). ecause of the potential impacts of a project like ki Yellowstone, these kinds of evidence should ave been gathered and documented by Forest ervice personnel each year since the development roposal was made.

e feel that Forest Service and Fish and Wildlife ervice personnel have not demonstrated an dequate ecological perspective of grizzly bear eeds in the Yellowstone Ecosystem. They isolated nd examined the Mount Hebgen area as an island of abitat and paid little attention to habitat uality, geographical position, or human pressures n surrounding areas; nor did they relate that nformation to grizzly bear ecology and the Mount ebgen management problem. Knight and Blanchard 1984) expressed similar concerns, noting that lthough food and cover on the Mount Hebgen site ay not be critical to the Yellowstone grizzly ear population, the proposed development has the otential to become a population sink that could ave serious negative impacts upon grizzlies.

n the summer of 1984 the Forest Service initiated ts newly formed Cumulative Effects Analysis rocess (Puchlerz and others 1984) in the Mount ebgen area. The results of such analysis, if ccompanied by more intensive surveys of grizzly ear and ungulate activity and a broader perspec- ive of the Yellowstone grizzly bear situation, ould provide a more realistic evaluation of rizzly bear habitat in the Hebgen area and a more ppropriate delineation of management situations. t is our hope that the Forest Service will roceed along these lines.

lark's River Corridor.--Our second example of nadequate evaluation of grizzly bear habitat by he Forest Service comes from the Clark's Fork iver Corridor in the Shoshone National Forest northwestern Wyoming).

n 1978, the Forest Service began to study the otential for a snowmobile route from Cooke City, T, to Crandall Junction, WY, through the Clark's ork Corridor. The proposed route would use xisting cleared trailways but would cross grizzly ear habitat. When grizzly bear management ituations were delineated in this area in 1979, he Forest Service classified the Clark's Fork orridor as MS 2 and MS 3, although area urrounding the corridor on three sides was lassified as MS 1 (USDA and USDI 1979; fig. 2). lassification of the corridor was ecologically nfounded and was instead based upon land wnership and political concerns (KRA Natural esource Consultants 1983).

n 1982, the Forest Service released its final nvironmental Assessment for the proposed project, eporting that the project would have little envi- onmental impact. The Forest Service concluded hat there would be no effect on threatened or ndangered species and consequently did not onsult with the U.S. Fish and Wildlife Service egarding the project. The Forest Service evaluation of grizzly bear habitat along the proposed trail route was based solely on importance values (Mealey 1977) for existing vegetative types (USDA 1982).

In October 1983, a private landowner hired Kopec-Reid Associates (now Reid Environmental Services) to investigate and document grizzly bear use of the Clark's Fork Corridor. KRA based its investigation on the common sense approach that we have outlined, and obtained data that refuted Forest Service conclusions about the area's value to grizzly bears (KRA Natural Resource Consultants 1983). First, KRA used IGBST data to show that home ranges of 12 radio-collared grizzlies included portions of the Clark's Fork Corridor (fig. 2) and that the study bears used the corridor primarily during spring and fall. KRA sampled habitat along the corridor and documented the occurrence of high-value grizzly bear habitat components. An ungulate survey revealed significant use of the corridor by moose, and a survey of grizzly bear activity indicated that grizzlies were present and preyed upon moose during fall, 1983. Study results also indicated that suitable grizzly bear denning habitat was available adjacent to the corridor.

The following example illustrates the inadequacy of the Forest Service habitat evaluation process. The Forest Service assessment showed the absolute and relative weightings of grizzly use of One Mile Creek, along the Clark's Fork Corridor, to be zero (USDA n.d., field notes by B. Haflich); that is, One Mile Creek had no value to grizzly bears. KRA surveys revealed that moose use One Mile Creek during spring and fall and that grizzlies had fed on a moose carcass in the One Mile Creek drainage. The point of this example is that use of habitat importance values to determine grizzly bear habitat quality should be accompanied by review of known data and intensive on-the-ground ungulate and grizzly bear use surveys during appropriate seasons.

West Gardiner Unit.--Our third and most recent example of grizzly bear habitat evaluation is from the West Gardiner unit of the Gallatin National Forest. In 1977, the Forest Service began to explore the possibility of increasing public access into the Mol Heron Creek drainage (USDA 1977), which flows from the northern boundary of Yellowstone National Park into the Yellowstone River. By 1983 the Forest Service had expanded its intentions, deciding that increased access into five major drainages of the West Gardiner unit would be desirable. In September 1984, the Forest Service released an Environmental Assessment (EA) of the proposed access program (USDA 1984). The EA and accompanying Biological Evaluation were extremely vague and lacked specific details regarding proposed actions and environmental impacts of those actions. Although all areas under consideration were within Occupied Grizzly Habitat (USDA and USDI 1979), few data were presented relating to potential or actual grizzly bear use of those areas or to potential impacts to grizzly bears. The EA included a listing of IGBST-instrumented bears that used the

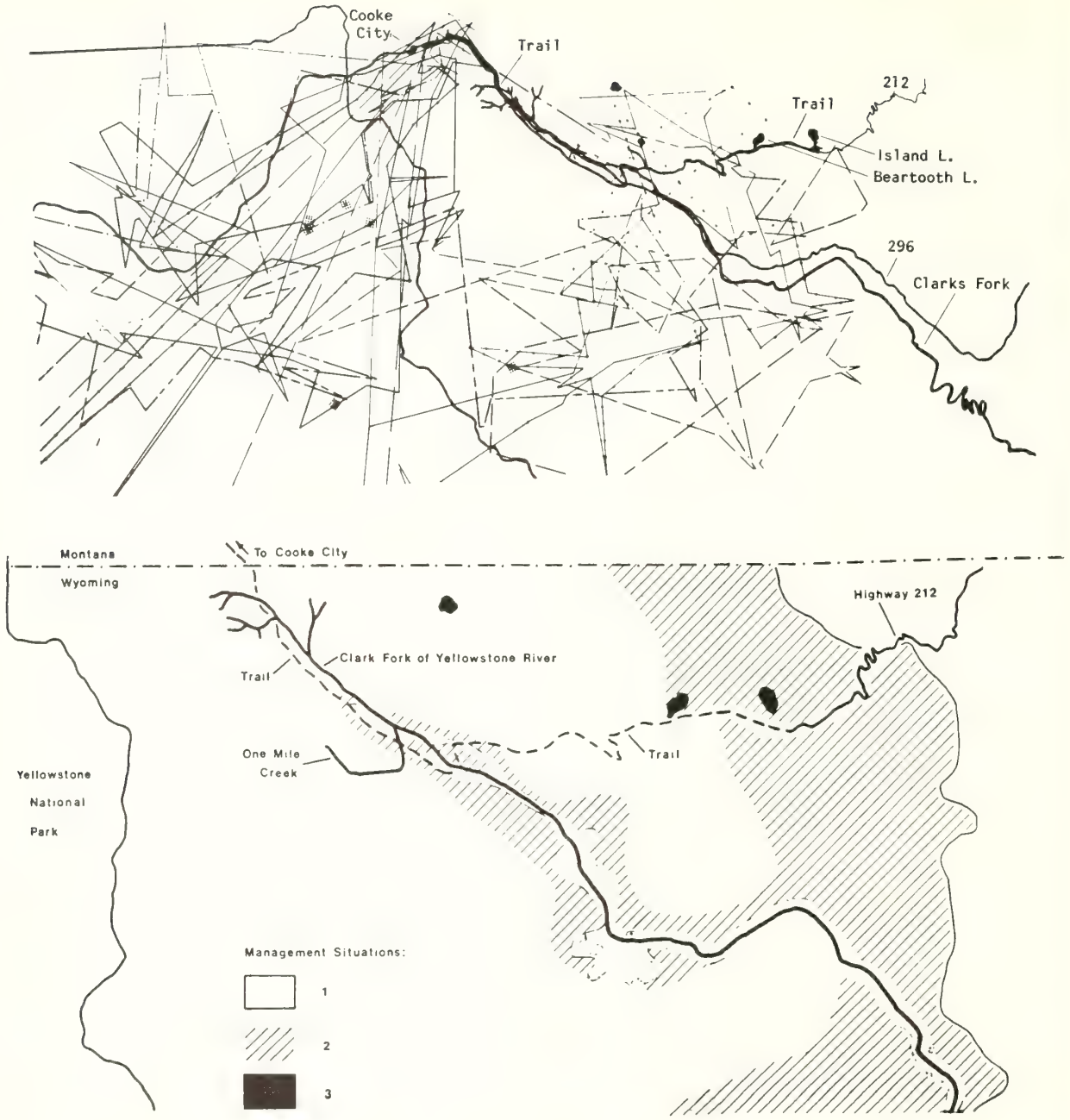


Figure 2.--Life ranges of 12 radio-instrumented grizzly bears (top), and delineations of management situations (bottom) in the Clark's Fork Corridor, Shoshone National Forest.

study area and some general information regarding cub production and denning by grizzlies in the Yellowstone Ecosystem (USDA 1984). No analyses of previously collected grizzly bear use data were presented, and no field work was conducted as part of the Forest Service evaluation process.

Out of concern for their land, their lifestyles, and the natural resources of the area, landowners, residents, and users of the West Gardiner unit formed a group (the Northern Yellowstone Rim Alliance) and hired Reid Environmental Services to investigate natural resource issues related to the Forest Service proposal. Preliminary planning and collection of background information began in January 1984, and field work began in early May. The majority of our work centered around evaluatio of the area as grizzly bear habitat.

We examined all IGBST data pertaining to the West Gardiner unit and constructed maps of radio-locations, recorded sightings, and life ranges of grizzly bears. This information alone demonstrated significant use of the area by grizzlies between 1974 and 1984.

Our own field work consisted of (1) interviews with residents and users of the area, (2) extensive surveys of grizzly bear and ungulate activity in all drainages included in the access proposal, (3) intensive sampling and mapping of grizzly bear habitat components in selected portions of the area, and (4) reconnaissance of potential denning habitat.

During this process we collected and documented locations of bear scats and samples of bear hair, located ungulate carcasses fed upon by grizzlies, located numerous grizzly bear day beds and several grizzly bear dens, made overlays of grizzly bear habitat components in the selected areas, documented sightings of grizzly bears by residents and users of the area, and documented seasonal habitat use patterns of ungulates.

Overall, we documented relatively high use of the area by grizzlies during spring, summer, and fall, 1984. Our data plus those of the IGBST indicate that grizzly bear use of the area is substantial and that management situation delineations do not accurately reflect grizzly bear use of the West Gardiner unit. Again, we believe that a common sense approach has led to a more realistic evaluation of grizzly bear habitat than have Forest Service procedures.

REDEFINING MANAGEMENT SITUATIONS

Ultimately, we believe that a more conservative view of critical grizzly bear habitat, such as the delineation presented by Craighead (1980), is needed in the Yellowstone Ecosystem until the grizzly bear population recovers. However, we realize that such a change may be unrealistic under current management constraints. If the current system is to be followed, we feel that grizzly bear management situations for the Yellowstone Ecosystem need to be redefined, and in many instances redelineated, to more accurately reflect grizzly bear habitat use and needs. Many MS boundaries reflect political, social, or economic convenience and do not correspond to the ecologically based definitions of management situations. We propose the following redefinition of management situations, based on ecological and management considerations:

Management Situation 1: All public land within occupied grizzly habitat (USDA and USDI 1979); grizzly bear recovery is the main priority.

Management Situation 2: The fringe of public lands outside of occupied grizzly habitat, representing an ecological buffer zone to MS 1; these areas are used by grizzlies for various reasons but do not represent population centers.

Management Situation 3: Private land within occupied grizzly habitat and the ecological fringe surrounding it; private activities in these areas could jeopardize the grizzly population; agency jurisdiction is limited.

Management Situation 4: Private land outside of occupied grizzly habitat and the ecological fringe surrounding it; activities on these lands are not likely to jeopardize the grizzly population; agency jurisdiction is limited.

Management Situation 5: Public land outside of occupied grizzly habitat and the ecological fringe surrounding it; lands occasionally used by grizzlies but activities not likely to jeopardize the grizzly population; management issues should be decided on a case-by-case basis.

If management situations are redefined in this manner, we believe they will more realistically represent grizzly bear needs and jurisdictional concerns of management agencies. On the basis of our evaluation we suggest reevaluating grizzly bear habitat in 11 areas of the Yellowstone Ecosystem (fig. 3).

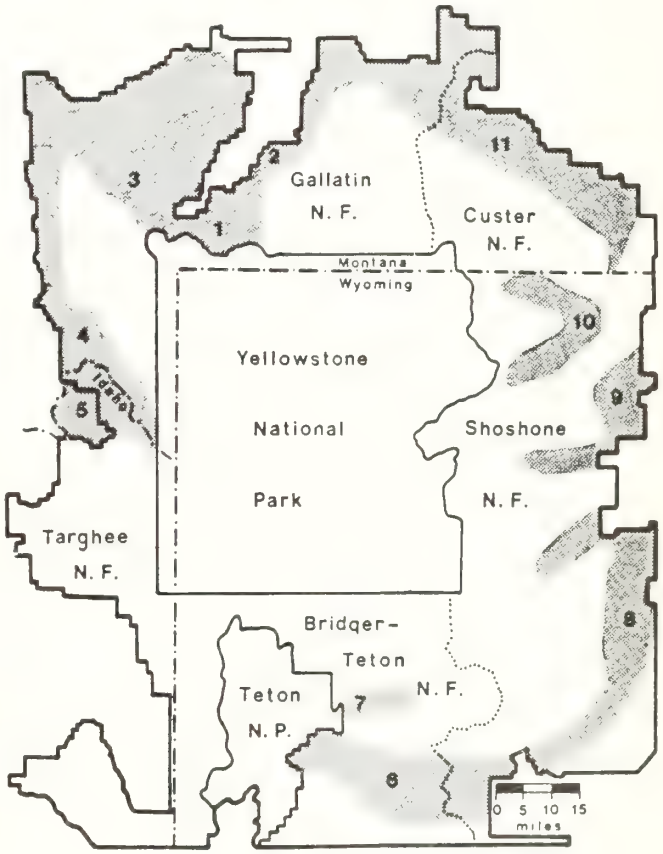


Figure 3.--Locations of areas within the Yellowstone ecosystem that need reevaluation of grizzly bear habitat: 1, West Gardiner unit (Gallatin National Forest); 2, West front of north Absaroka Range (Gallatin National Forest); 3, Southern Gallatin Range (Gallatin National Forest); 4, Hebgen Lake-West Yellowstone area (Gallatin National Forest); 5, Henry's Lake-Island Park area (Targhee National Forest); 6, Gros Ventre River (Bridger-Teton National Forest); 7, Area east of Moran Junction (Bridger-Teton National Forest); 8, Shoshone River System (Shoshone National Forest); 9, Sunlight Creek-Crandall area (Shoshone National Forest); 10, Clark's Fork of the Yellowstone River (Shoshone National Forest); 11, Boulder-Stillwater River Systems (Gallatin National Forest, Custer National Forest).

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AVAILABILITY/UTILIZATION OF GRIZZLY BEAR HABITAT COMPONENTS ON THE ROCKY MOUNTAIN EAST FRONT

Keith Aune and Tom Stivers

ABSTRACT: Seventeen grizzly bear habitat components have been identified on the Rocky Mountain East Front and the availability/utilization of those components was assessed as part of the East Front grizzly studies. Habitat utilization was determined through habitat data gathered at the sites of 1,400 radio relocations during 1980-84. Habitat availability was determined through a nonmapping technique using 5,600 random points within occupied habitat. The analysis identified several habitat components that are used significantly more or less than the seasonal availability. Those components are discussed in detail. An analysis of the availability/utilization of habitat components in relation to roads has also been completed. The road analysis indicated that for spring range, while most of the preferred habitat components are near roads, the use of preferred components away from roads is greater than their availability.

This information is available in:

Aune K; Madel, M.; Hunt, C. Rocky Mountain Front grizzly bear monitoring and investigation. Helena, MT: Montana Department of Fish, Wildlife, and Parks; 1986. 239 p.

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Aune, K.; Stivers, T. Ecological studies of the grizzly bear in the Pine Butte Reserve. Helena, MT: Montana Department of Fish, Wildlife, and Parks; 1985. 153 p.

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Session III—General Habitat Considerations

Chaired by:

L. Jack Lyon, Research Biologist and Project Leader, Intermountain Research Station, Missoula, MT

USING SATELLITES TO EVALUATE ECOSYSTEMS AS GRIZZLY BEAR HABITAT

John J. Craighead, F. Lance Craighead and Derek J. Craighead

ABSTRACT: Remote sensing has proven to be a precise, highly quantitative tool for describing, mapping, and evaluating grizzly bear habitat on an ecosystem basis. Using the Landsat satellite's multispectral scanner system (MSS), habitat maps of a 4,592 km^2 (1,773 mi^2) area were constructed and refined in Montana's Lincoln-/Scapegoat and Bob Marshall wilderness areas. This technique was further tested in northwest Alaska over a 4,144 km^2 (1,600 mi^2) area. Several satellite systems currently gather spectral data from the surface of the earth. These data, recorded on four to seven spectral bands, are a measure of the reflectance of vegetation and other surfaces. To relate digital image data to vegetation types, intensive ground-truthing (botanical sampling) is needed. A simple, replicable, relevé-type of sample plot is discussed, as well as techniques of interpreting these data and applying them to ecological studies. An agreed-upon, standardized method of describing vegetation with satellite mapping is needed as applications of the technique become widespread. Using standardized techniques, entire ecosystems can be mapped, quantified, and interpreted in terms of vegetation complexes, which are vegetation/ habitat types with similar spectral reflectance values. These large units and their subunits can be described in terms of percent coverage and percent occurrence of plant species. Comparisons can then be made between ecosystems on all or some of these levels. This technique is presently the only practical method for obtaining precise quantitative data on an ecosystem basis and for making meaningful comparisons among ecosystems.

INTRODUCTION

In North America, designated wilderness areas are essential habitat for grizzly bears; they protect the last remaining pristine conditions of native flora and fauna. To preserve the ebb and flow of wilderness for social, aesthetic, and scientific purposes, it is necessary to learn more about the intricate interplay of fauna and flora. Compiling baseline data on the species and plant communities is the necessary first step, and using satellite imagery is the most promising method for obtaining this information over large areas of wilderness.

Paper presented at the Grizzly Bear Habitat Symposium, Missoula, MT, April 30 - May 2, 1985.

John J. Craighead is Director and F. Lance Craighead and Derek J. Craighead are biologists, Wildlife-Wildlands Institute, Missoula, MT.

At this point in the development of satellite mapping techniques it would be wise to standardize the methods used in delineating vegetation complexes (vegetation/habitat types with similar spectral reflectance values) and in collecting sample plot data. The methodology developed in a study of grizzly bear habitat in the Lincoln/ Scapegoat Wilderness Area in Montana (Craighead and others 1982) was further tested and refined in a recent study which mapped the area surrounding the Squirrel River in northwestern Alaska where the intergradations between vegetation complexes were, in many cases, more subtle than those encountered in Montana. The techniques used to produce accurate habitat maps describing vegetation complexes in terms of plant species and plant communities, and the practical applications of this technology for the management of wildlife on an ecosystem basis, are the subject of this paper.

THE MAPPING SYSTEM

The Landsat satellites gather a continuous series of digital images of the earth's surface from a polar orbit at an altitude of about 900 km (560 mi) using scanning systems that record radiant energy over a wide spectrum of wave lengths. The multispectral scanning system (MSS) collects the digital image data that were used to define ecological vegetation complexes in wilderness areas in Montana and Alaska.

The basic spectral unit, the picture element or "pixel," represents a rectangular area on the earth's surface of 4,530 m^2 (48,761 ft^2) with the MSS imagery. Landsat thematic mapper (TM) data can define a smaller area, about one-fifth this size: 900 m^2 (9,688 ft^2). A pixel defines the lower limit of resolution of the system; the reflectance over the entire pixel is averaged to give a single value. This means that in many instances the mapping system is useful for applications varying in scale from 0.09 ha (1/5 acre) to the area of an entire ecosystem. Using a digital image analyzer interactively, color-coded maps are constructed pixel by pixel from the multispectral data. When merged with topographic models (1:63360 to 1:250,000) of the area, a digital map and data base are produced as the final product of this mapping system.

The term "ecosystem," as used here, refers to a large biogeographical area supporting a common ecological vegetation classification. An ecosystem can be classified into a number of vegetation complexes (10 to 20) using spectral data gathered by the satellite scanner. These

areas of similar spectral reflectance usually represent areas of similar vegetation. Vegetation sample plot data (or "ground-truth") from each of these complexes can then be used to describe each complex in terms of percent cover and frequency of occurrence of plant species and plant communities. Any of a number of intermediate habitat-type groupings, such as forest habitat types (FHT), ecological land units (ELU), or plant series, can be used depending on the needs of the user (Craighead and others 1982).

SATELLITE TECHNOLOGY

Scanning Systems

Three currently operational systems are the most promising for ecosystem mapping and evaluation. They provide digital image data of the earth's surface with different degrees of resolution. The thematic mapper (TM) has the finest resolution, followed by the multispectral scanning system (MSS), and the advanced very high resolution radiometer (AVHRR). The TM and MSS systems are aboard Landsat satellites that orbit the earth at altitudes varying from 900 to 949 km (560 to 590 mi). Each satellite makes 14.5 sun-synchronous, polar orbits per day, completing an orbit every 103 min. They scan adjacent areas on successive daily orbits, moving from east to west, covering the earth's surface every 16 days and thus updating any particular area at 16-day intervals.

The NOAA satellites, with the AVHRR system, provide digital image data with less resolution than the Landsat systems. The NOAA satellites are also sun-synchronous, polar orbiting, at an altitude of 850 km (527 mi) and a period of 102 min.

Multispectral Scanning System (MSS)

The MSS records digital image data in four spectral bands: band No. 4 (0.5 to 0.6 um), band No. 5 (0.6 to 0.7 um), band No. 6, photographic infrared (0.7 to 0.8 um) and band No. 7, near infrared (0.8 to 1.1 um). The intensity of reflected radiation is recorded as a continuous data strip. This is later converted into a series of frames, each covering an area of 185 by 185 km (115 by 115 mi). Data from two bands, Nos. 5 and 7, were used to define the spectral signature of vegetation complexes in the Montana and Alaska studies.

Thematic Mapper (TM)

The TM records digital image data in seven spectral bands. For habitat mapping, band No. 2, (0.52 to 0.6 um) and the near infrared band No. 4, (0.76 to 0.90 um), are generally used. The distinct advantage in using TM data is the finer resolution. In many cases this should allow finer distinctions to be made in mapping smaller vegetation units. In other cases, especially when mapping large areas, such resolution may be more confusing than helpful. A positive advantage of the thematic mapper over MSS is the significant increase in gray level (signal quantization level) values (64 for MSS versus 256 for TM). This allows finer distinctions to be made in differentiating habitat types. The new French SPOT satellites will also provide high resolution data.

Advanced Very High Resolution Radiometer (AVHRR)

The AVHRR system uses a much larger mapping unit than either of the Landsat systems. Each pixel covers an area of 1 km^2 (2.6 mi^2). The area of a single frame is 1 100 km (684 mi) long by 2 700 km (1678 mi) wide, approximately 220 times as large as a Landsat frame. The newer NOAA satellites record data on seven bands that include three thermal channels. The red (0.55 to 0.68 um) and near infrared (0.73 to 1.1 um) bands are wider than the MSS bands but are adequate for mapping green vegetation (Tucker and Gatlin 1984). Because of the wider swath width, more frequent but less definitive area coverage is possible. It should be useful to map large areas of less diverse vegetation such as the North Slope of Alaska and to show seasonal phenology of growth and development.

Each system has advantages and disadvantages, but all have useful applications and can complement one another in studies involving a number of ecosystems. Because of the inherent problems in satellite scanning (cloud cover and timing of satellite passes), one system may have the necessary coverage of an area when another does not.

GROUND-TRUTHING

To use any satellite system to map vegetation, a direct relationship must be established between the digital data and the vegetation that it represents. Techniques to accomplish this are termed "ground-truthing". Four ground-truthing techniques were used.

1. In Montana a vegetation-type map of the primary study area was initially produced, on the ground, for subsequent comparison with the satellite digital map.
2. Aerial photographs, aerial reconnaissance, and site visits determined training sites: i.e. large homogeneous areas of vegetation that represent a vegetation complex.
3. Digital maps were taken into the field and the boundaries of vegetation complexes were compared with the actual habitat boundaries.
4. Descriptive data were compiled from vegetation sample plots located in each vegetation complex.

In Montana, relevé-type plots recording estimates of cover were used for sample data. Percent cover in herbaceous community types was estimated to the 5 percent level on plots of 108 m^2

(1,156 ft^2). Forest vegetation was sampled similarly on plot sizes of 809 m^2 (8,708 ft^2). Species occurring at less than the 5 percent level were recorded as trace species. Percent cover was estimated for three strata: tree (>3 m), shrub and dwarf tree (0.6 m to 3 m), and ground cover. Ground cover plus bare ground was estimated to equal 100 percent.

In Alaska, the same plot sizes were used. Percent cover was estimated to the 1 percent level on all plots. In addition to the three strata estimated in Montana, an attempt was made to estimate coverage of a sublayer of sphagnum and lichen species whenever possible.

STUDY AREAS

Representative study areas for intensive ground-truthing are essential to the mapping system. These can be small and numerous or large and few. They must represent the full range of vegetation within the ecosystem, so that study site data can be extrapolated to other areas of the ecosystem.

From 1977 to 1982 a comprehensive vegetation map was developed and refined for a 4,592 km^2 (1,773 mi^2) area in the Lincoln/Scapegoat and Bob Marshall Wildernesses in central Montana (fig. 1). Initially, a detailed vegetation ground map was developed in the 204-km^2 (70-mi^2) primary study area. A first-generation Landsat map was then ground-truthed in this area to produce a refined, second-generation Landsat map.

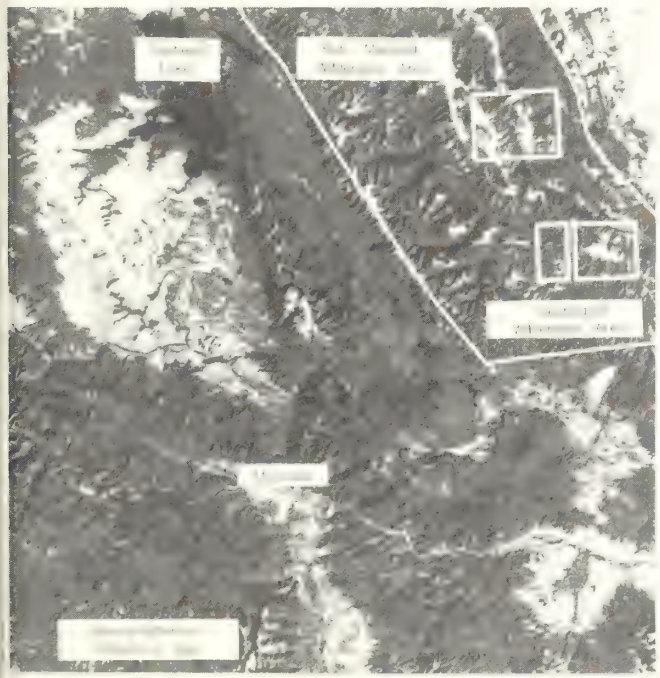


Figure 1.--The Montana study areas: 1) Scapegoat Plateau--primary study area; 2) Slategoat Plateau--secondary study area; 3) Danaher--secondary study area.

The second-generation classifications were extrapolated to secondary study areas, Slategoat and Danaher. Here additional ground-truthing verified the accuracy of the extrapolation process to a total area of 645 km^2 (249 mi^2). On the basis of this and extensive ground surveys, a third refinement was made in order to accurately extrapolate the resultant vegetation complexes from this third-generation map to the entire 4,592 km^2 (1,773 mi^2) area (fig. 2).

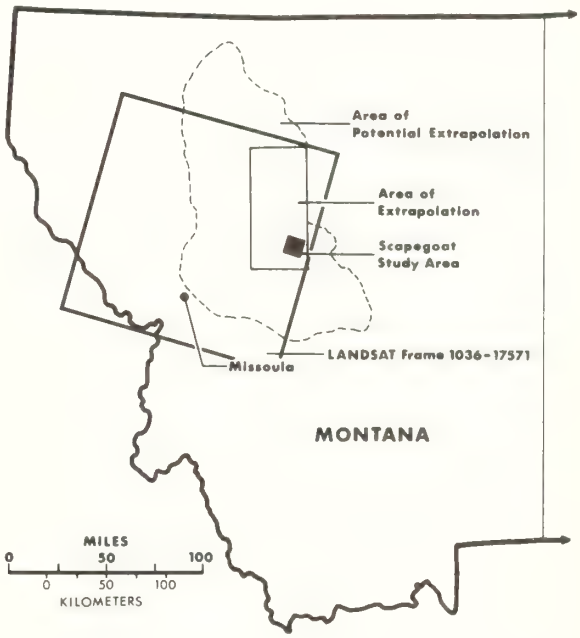


Figure 2.--The Montana study areas: area of extrapolation of third-generation map.

In 1983 and 1984, first- and second-generation maps were developed for a 4,144-km^2 (1,600-mi^2) area in northwestern Alaska, which encompassed the Squirrel River and the Kobuk River Delta (fig. 3). Ground-truthing sites were scattered throughout the area as shown.

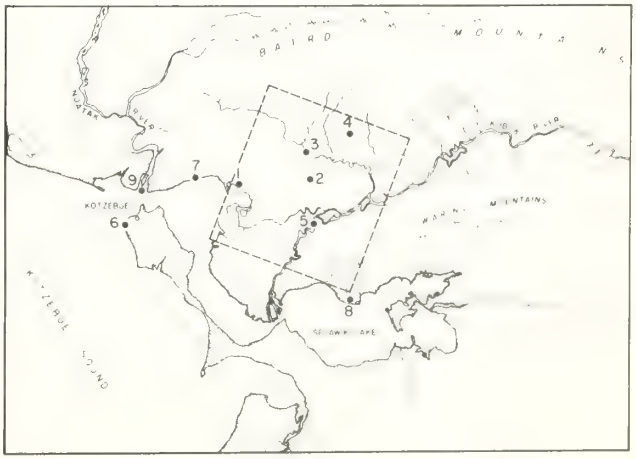


Figure 3.--The Alaska study area: 1) Kobuk Peak; 2) Kiana Hills; 3) Squirrel River; 4) Baird Mountains; 5) Kobuk Delta; 6) Baldwin Peninsula; 7) Kobuk Lake; 8) Selawik Lake; 9) Noatak River.

ECOSPECTRAL CLASSIFICATION

Converting digital image data into useful ecospectral classifications that represent natural plant groupings is an iterative process that requires two or three successive refinements (Craighead and others 1982). An overview of the process is depicted in figure 4.

Initially, a cloud-free digital tape of the area of interest is obtained from an EROS Data Center, and study sites are tentatively located on the imagery. This is followed by a reconnaissance of the proposed study areas, examination of high-altitude photos (color and infrared), and on-site inspections. Large areas of homogeneous vegetation representing distinct classes of vegetation (for example, forest, tundra, shrubland) are precisely located on topographic maps or orthophotos to be used as training sites, which are areas of known location with a relatively uniform vegetation type throughout the study area. Generalized ground-truth information is obtained, and limited vegetation sample plots are taken. By analyzing the digital data from training site locations on the satellite imagery, a characteristic composite of spectral values, or a "signature," is computed and assigned to each vegetation complex. Data from several training sites are averaged to determine each signature. An ecospectral classification results, with each spectral group or vegetation complex assigned a color code. Then, using the digital image analyzer (IMAGE 100) interactive computer, a computer map is constructed with areas of similar vegetation having the same color code. When using a supervised classification technique such as this, the type of vegetation in each complex is known beforehand, but the exact botanical composition of each complex is unknown. To determine what each vegetation complex represents on the ground requires botanical sampling. Once this has been accomplished, the colored mosaic of complexes with their botanical descriptions then comprise a thematic vegetation map.

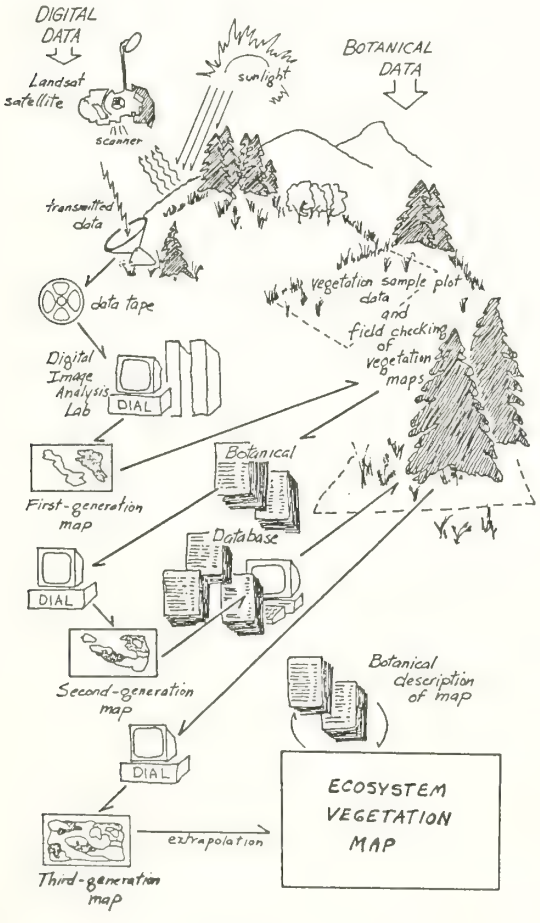


Figure 4.--An overview of the mapping process.

The type of vegetation complex that can be resolved from a spectral signature is limited by the resolution of the scanning system. Thus, it is necessary to first construct a vegetation map of the spectral groups and then describe these spectral groups or vegetation complexes in terms of their botanical composition from on-the-ground studies. When a hierarchical vegetation classification is used to describe the vegetation representing each spectral group, the result is a spectral-vegetation classification, or "ecospectral classification" (Craighead and others 1982). Attempts to generate spectral values for predetermined vegetation groupings have not proved productive, and such efforts were responsible for some early disillusionments with Landsat as a mapping system.

Montana

In the Montana study, three successive classification refinements were made in the habitat map. This was accomplished as follows. Using the first-generation ecospectral map, sample plots were located in representative areas to describe each of six vegetation complexes. During the 1975 and 1976 field seasons, 487 sample plots were taken. Systems existed for habitat-typing forests and grass-shrublands, and each sample plot could be assigned to a forest habitat type (FHT) (Daubenmire and Daubenmire 1968; Pfister and others 1977) or ecological landtype (ELT) (Mueggler and Handl 1974). No comparable system existed for typing alpine vegetation, so a classification was developed using the ecological land unit (ELU) (Corliss and others 1973) as the basic grouping of similar plant communities. The vegetation complex, each with a unique spectral signature, could represent any one of a number of vegetation system/land system combinations. For example, the alpine meadow complex (fig. 5) was a community-type land unit, whereas the xeric Pinus albicaulis forest complex (fig. 6) was a series-landtype association of forest habitat types. Both complexes are subdivided to the plant community and species level. The larger units of the system are expressed in percent area; the smaller units in percent vegetation cover.

These basic vegetation groupings were further distinguished by altitudinal zones. Originally

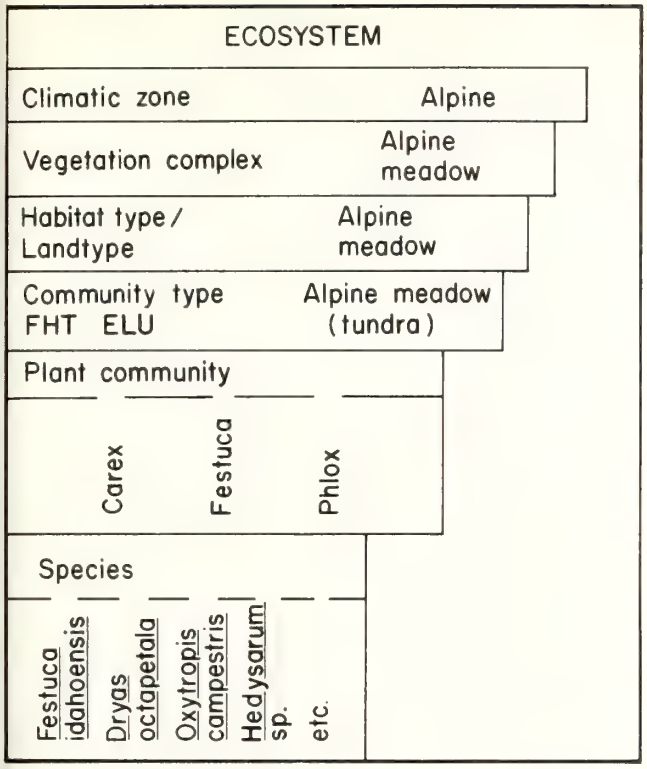


Figure 5.--Sub-divisions of the alpine meadow vegetation complex.

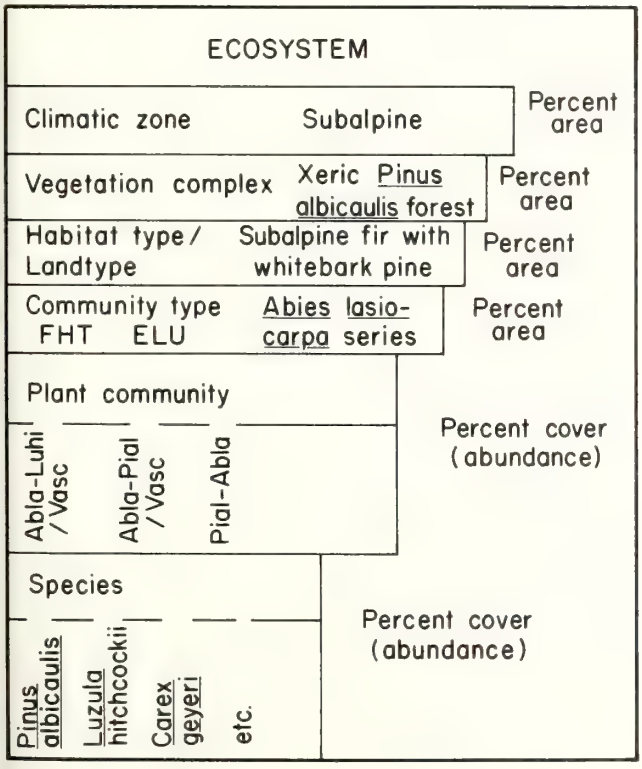


Figure 6.--Sub-divisions of the xeric Pinus albicaulis forest complex. Large units of the system are expressed as percent area; small units as percent cover.

only six spectral signatures were used to delineate vegetation complexes; however, sample plot data indicated a difference in plant composition above and below 2,317 m (7,600 ft) for one complex, which was then divided into the alpine meadow and subalpine parkland complexes by means of a "signature polygon." A signature polygon is a discrete area delineated by digitized elevation data and spectral signatures. The digital image analyzer is used to assign a different color to this area and to separate it as a recognized vegetation complex. Similarly, another vegetation complex was differentiated into mesic subalpine fir and mixed coniferous forest by a signature polygon drawn at the 2,317-m (7,000-ft) contour. The ground-truth map of the primary study area was then checked against the habitat map developed from digital image data. (For more details see Craighead and others 1982).

These eight spectral signatures from the Scapegoat primary study area were then used to generate maps of the Slategoat and Danaher secondary study areas. The resultant maps were termed second-generation maps. Test sites were established in the secondary study areas to determine the accuracy of the extrapolation.

After field-checking the second-generation map and taking additional sample plots, a third-generation map was developed utilizing nine spectral and four polygon signatures to delineate 13 vegetation complexes. This map showed an accuracy of 93 percent and was subsequently extrapolated to a 4,592-km^2 (1,773-ft^2) area of wilderness surrounding the Scapegoat study area.

Alaska

In the Alaska mapping project of 1983-85, two generations of digital image maps have been developed. Experience from the Montana study enabled the methodology to be streamlined somewhat. Training sites were located on U.S. Geological Survey maps, and after aerial reconnaissance, 40 sample plots were taken in representative plant communities. These data were used to develop a first-generation map of 12 vegetation complexes. This map was field-checked during the summer of 1984. To botanically describe the vegetation complexes identified from spectral values, 627 sample plots were taken in representative plant communities. In Alaska, a comprehensive, hierarchical system of vegetation classification had already been established (Viereck and Dyrness 1980; Viereck and others 1982), and it was only necessary to incorporate it into the spectral classifications obtained from satellite data to develop an ecospectral classification. As in Montana, a spectral signature for a vegetation complex could represent a wide or a narrow range of plant groupings (fig. 7). Some complexes such as the feltleaf willow complex (Salix alaxensis) represented only one plant community but registered a consistent, distinctive reflectance value. The greenleaf

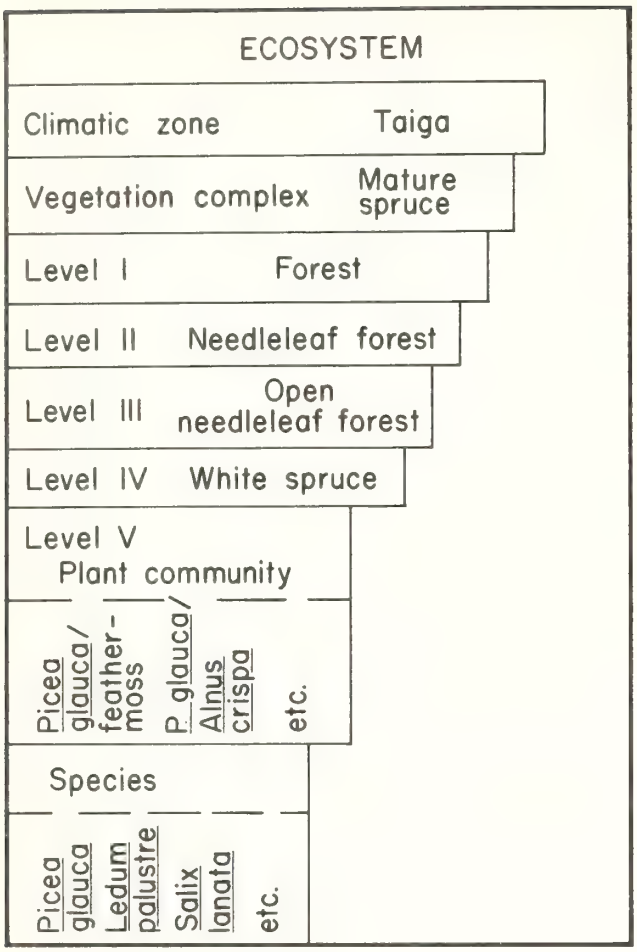


Figure 7.--Sub-divisions of the mature spruce vegetation complex.

willow complex was also distinctive but comprised 11 plant communities with three codominant willow species: Salix lanata, S. planifolia, and S. glauca. Other complexes such as the tussock tundra complex represented a still greater variety of plant communities composed of several codominant species.

A second-generation map was developed in early 1985 by adjusting signature polygons to comply with elevational field data and vegetation surveys. In the Kobuk delta region, several distinctive signatures were grouped into a riparian vegetation mosaic to produce a less confusing color map. We are in the process of extrapolating the classification to an area of approximately 129,500 km^2 (50,000 mi^2).

SAMPLE PLOT ANALYSIS

Sample plot data were grouped according to the vegetation complex in which they were collected and summary statistics were computed. In the Montana study, the data were further divided subjectively into ecological land unit (ELU), ecological land type (ELT), and forest habitat type (FHT) groupings. By type-mapping the entire primary study area, relative abundance of each type in a vegetation complex was determined. Percent vegetative cover of each species was determined from sample plot data by dividing the total percent cover for each species by the total percent cover for all species and percent occurrence of plant species was determined in a similar manner: if a species represented 5 percent or more of the cover within a plot, it was counted as occurring in that plot. The total percent occurrence for a species was determined by dividing the total number of plots in which the species occurred by the total number of plots taken in the specific ELU, ELT, or FHT (Craighead and others 1982).

In the Alaska study, sample plot data were entered into a separate computer data base for each vegetation complex in which they occurred. Summary statistics for each species were computed in the vegetation complex and calculated percent vegetation cover and percent occurrence. Average ground cover was determined by dividing the sum of all recorded cover estimates by the number of plots taken in that vegetation complex, which gave an average percent cover of that species in any plot.

Vegetation sample plots were then subjectively grouped into plant communities, based on the classes compiled by Viereck and Dyrness (1980) and Viereck and others (1982) to estimate the relative coverage of each plant community in a vegetation complex. Plant community descriptions are incomplete for some habitat types in northwestern Alaska and several new descriptions resulted.

CAPABILITIES OF THE MAPPING SYSTEM

The mapping system is not limited to classifying large vegetation units defined by spectral signatures. Units smaller than the vegetation complex can be computer mapped but cannot be extrapolated. If for example, there is an area of interest of from 0.38 to 76.8 km^2 (1 to 20 mi^2) containing a drainage pattern or a series of mountain slopes that needs to be mapped and quantified, this can readily be done. First, the latitude and longitude of the area of interest is determined. The area can then be located on the MSS digital tape and video displayed. Signature polygons can be developed for the riparian habitat or for any number of vegetation sites or animal use locales known to exist within the area. These can be as discreet as a single, large plant community or a combination of several of these. Similarly, land form units as small as the ecological land unit (ELU) or a site of high animal use about 0.4 ha (1 acre) in extent can be mapped. Color codes are assigned, and thus a color-coded or thematic map with units more definitive than the vegetation complex can be computer-constructed and then printed and enlarged for field use.

These maps can be used to interpret similar small land areas located throughout the ecosystem even

though the data cannot be extrapolated to other areas. Both the small polygon-defined sites and the large spectrally defined vegetation complexes are subject to total area computation and to statistical analyses of interspersion, juxtaposition, and habitat diversity.

To further illustrate the application, assume there is a 25.9-km^2 (10-mi^2) area of heavily used grizzly bear habitat. In this area, vegetation complexes (which can be extrapolated to the entire ecosystem) and small dispersed areas 0.4 to 4.0 ha (1 to 10 acres) of riparian marshland and specific avalanche slopes (which cannot be extrapolated) need to be mapped. This area can be mapped by applying data gathered in the field. Polygons are drawn around all the specific sites using an interactive computer. These are color coded and incorporated into the digital base map displaying the vegetation complexes. Readouts of area statistics can be obtained for both the large and the small units. Any site of specific interest that can be located in the field or identified from aerial photographs can be delineated on the digital image map and assigned an identifying color. The total area of any site or group of similar sites is instantly available from the digital map data base. Using a satellite imagery data base can thus enhance and clarify aerial photography mapping efforts and, conversely, conventional mapping techniques can be integrated with the digitized ecosystem classification.

ECOSYSTEM ANALYSIS

Ecosystems accurately mapped and quantitatively described can be compared to show existing similarities and differences using one or more of the satellite imagery systems (MSS, TM, and AVHRR). This can be accomplished at a number of levels. Starting with the larger classification units, comparisons can be made of bioclimatic zones: the vegetation of the alpine zone of one biogeographic area with the alpine zone vegetation of another, the subalpine with subalpine, and temperate with temperate. Decreasingly smaller vegetation units such as forest series, vegetation complexes, forest habitat types (FHT), and plant communities can be compared and analyzed.

In addition to comparing specific vegetation categories between ecosystems, it is feasible to computer-analyze, from the digital data base, such parameters as ecological diversity, percent abundance of a specific plant, or the abundance of preferred bear food plants.

COMPARISONS AMONG ECOSYSTEMS

Comparing the Alaska study area at latitude 67° N with the Montana site at latitude 47° N presents a far more difficult task than comparing ecosystems that are more similar in geographic location and in terrain features; however, at the present time these are the only areas for which there are comparable data. These preliminary comparisons are offered primarily as illustrations of what is possible and what is needed. If and when the Yellowstone and Selway/Bitterroot areas are mapped by digital imagery, a more direct and comprehensive comparison can be made between these and the Northern Continental Divide than is possible between geographic sites in Montana and Alaska. These differences, as well as similarities, can be tabulated, quantified, and used to interpret habitat quality and habitat use by grizzly bear populations.

In general, ecosystem data can be compared on three levels. On a macroscale, comparisons can be made between similar vegetation complexes. On a microscale, species and plant communities can be compared. At the present time, the data from the Montana study area have not been analyzed in terms of plant communities so it will only be pointed out that this can be done. It may be that these comparisons of identical, or ecologically equivalent, plant communities will be the most meaningful in terms of grizzly bear ecology.

On a macroscale, data from the digital vegetation maps are summarized in table 1. The data have been grouped to allow comparisons to be made between the alpine zones, the forests, and the other complexes (herbaceous and shrubs). The alpine zones in both areas comprise a similar percentage of the total vegetation. On the other hand, the amount of forested areas is very dissimilar: 62.05 percent in Montana versus 22.64 percent in Alaska. The other vegetation complexes are scarcely comparable: the Alaskan area extends from sea level and has a greater diversity of herbaceous and shrubland habitat types as well as a significant amount of water. Any similarities in the two areas are most likely to be found in the alpine zones.

The alpine zones of both sites have similar terrain that can be divided by spectral values into two comparable complexes; the alpine meadow, or tundra, and the vegetated rock. Some microscale comparisons between these vegetation complexes are offered to illustrate how the comparative process can work.

Table 2 shows the percent vegetative cover in the vegetated rock complex. Only two species, Dryas octopetala and Silene acaulis, were identical; D. octopetala comprised almost three times as much cover in Alaska as in Montana. In Montana, bear food plants are almost 10 times as abundant as they are in the same vegetation complex in Alaska when only the bear food plants are compared:

	Alaska	Montana
Percent vegetation cover	5.4	46.8
Average ground cover	2.3	18.7

The Alaskan alpine tundra and the Montana alpine meadow complexes were also compared. Again, Dryas octopetala was the major identical species, comprising twice as much cover in Alaska (table 3), although several genera with similar species

Table 1.--Area comparisons: Montana and Alaska digitized vegetation maps

Montana vegetation complexes (159,456 acres)	Percent of total	Alaska vegetation complexes (886,949 acres)	Percent of total
Alpine		Alpine	
Alpine meadow	5.29	Alpine tundra	6.76
Vegetated rock	3.44	Vegetated rock	2.28
Bare rock I	4.50	Bare rock	.28
Bare rock II	3.58	Alpine shrubland	7.92
Subtotal	16.81	Subtotal	17.24
Forest		Forest	
Xeric Pinus albicaulis	4.77	Young dwarf spruce forest	15.12
Mesic Abies lasiocarpa/ Pinus albicaulis forest	11.89	Mature spruce forest	7.52
Xeric Abies lasiocarpa/ Pseudotsuga menziesii forest	9.08	Subtotal	22.64
Mixed coniferous temperate forest	36.31		
Subtotal	62.05		
Other		Other	
Subalpine parkland	7.37	Feltleaf willow	2.68
Temperate parkland	9.85	Greenleaf willow	5.18
Carex-Salix marsh	.70	Shrub tundra	6.84
Equisetum seepage	.27	Tussock tundra	27.40
Scree	2.44	Equisetum-sedge marsh	2.24
Unclassified	.51	Semi-vegetated areas	2.17
Subtotal	21.14	Bare gravel bars	.05
		Burn	2.28
		Water	11.27
		Subtotal	60.11
Total	100.00	Total	99.99

Table 2.--Vegetated rock complex species comparisons

Montana vegetation (n=70)	Percent	Alaska vegetation (n=15)	Percent
*Dryas octopetala	24.8	Dryas octopetala	71.22
**Carex spp.	19.2	Unidentified Carex spp.	1.43
Festuca idahoensis	10.5	Loiseluria procumbens	4.61
**Arctostaphylos uva-ursi	7.4	Arctostaphylos alpina/rubra	.16
**Salix spp.	5.3	Salix phlebophylla	12.40
Phyllodoce spp.	3.9	Diapensia lapponica	1.75
Juncus parryi	3.3	Carex membranacea	.79
Trace forbs	3.3	Trace forbs	3.18
Gramineae spp.	2.8	Unidentified Gramineae spp.	.95
Potentilla fruticosa	2.3	Oxytropis nigrescens	.64
Phlox pulvinata	2.3	Carex microchaeta	.64
Antennaria spp.	2.1	Hierchloe alpina	.48
Gentiana calycosa	1.3	Betula nana	.32
**Salix arctica	1.1	Artemesia arctica	.16
Claytonia megarhiza	1.0	Vaccinium uliginosum	.16
Potentilla diversifolia	1.0	Ledum palustre	.16
Ranunculus eschsholtzii	.8	Minuartia arctica	.16
Hedysarum spp.	.8	Carex scirpoidea	.16
Lomatium cous	.8	Empetrum nigrum	.16
Luzula hitchcockii	.7		
Arabis spp.	.7		
Achillea millefolium	.7		
Arenaria spp.	.5		
Anemone spp.	.5		
Cardamine rupicola	.5		
Penstemon ellipticus	.3		
Hedysarum sulphurescens	.3		
Claytonia lanceolata	.2		
*Silene acaulis	.2	Silene acaulis	.16
Fragaria virginiana	.2		
Besseya wyomingensis	.2		
Erigeron spp.	.2		
Erthronium grandiflorum	.2		
Pedicularis spp.	.2		
Valeriana spp.	.2		
Astragalus bourgovii	.2		
Saxifraga spp.	.2	Saxifraga oppositifolia	.32
Poa alpina	.2		
Total	100.4	Total	100.01

* Species that appeared in both Montana and Alaska (excluding trace species).
** Genera that appeared in both Montana and Alaska (excluding trace species).

Table 3.--Alpine tundra/meadow complex species comparisons

Montana vegetation (n=101)	Percent	Alaska vegetation (n=56)	Percent
**Carex spp.	19.5	Unidentified Carex spp.	21.46
Festuca idahoensis	15.2	Dryas spp.	3.23
*Dryas octopetala	6.5	Dryas octopetala	13.28
**Arctostaphylos uva-ursi	5.1	Arctostaphylos alpina/rubra	1.34
Phlox pulvinata	4.9	Dryas integrifolia	3.01
Thalictrum occidentale	4.3	Equisetum arvense	10.15
Luzula hitchcockii	3.6	Moss and lichen	8.25
Gramineae spp.	2.8	Unidentified Gramineae spp.	1.58
Ranunculus eschscholtzii	2.4	Carex bigelowii	6.90
Trace forbs	2.4	Trace forbs	2.03
**Salix arctica	2.3	Salix arctica	.82
**Oxytropis campestris	1.9	Oxytropis spp.	.05
**Potentilla fruticosa	1.9	Potentilla biflora	.18
**Anemone parviflora	1.8	Anemone narcissiflora	.04
Valeriana spp.	1.6	Salix reticulata	3.50
**Hedysarum spp.	1.6	Hedysarum alpinum	.22
Potentilla diversifolia	1.5	Betula nana	3.44
Caltha leptosepala	1.5	Eriophorum vaginatum	2.99
**Vaccinium scoparium	1.4	Vaccinium uliginosum	6.72
Gentiana calycosa	1.4	Vaccinium vitis-idaea	.18
Achillea millefolium	1.3	Cassiope tetragona	2.74
Erythronium grandiflorum	1.1	Empetrum nigrum	.88
Polygonum spp.	1.0	Ledum palustre	.84
Antennaria spp.	1.0	Lupinus arcticus	.56
Astragalus spp.	1.0	Hierchloe alpina	.45
Eritrichium nanum	.9	Boykinia richardsonii	.43
Astragalus bourgovii	.9	Calamagrostis spp.	.39
Juncus parryi	.7	Poa spp.	.36
Erigeron spp.	.7	Carex scirpoidea	.23
Arnica latifolia	.6	Allium schoenoprasum	.22
Erigeron simplex	.5	Salix phlebophylla	.16
Lomatium spp.	.4	Heracleum lanatum	.16
Senecio triangularis	.3	Arctagrostis latifolia	.14
Arenaria spp.	.3	Mertensia paniculata	.09
Douglasia montana	.3	Geum glaciale	.07
Senecio megacephalus	.3	Eriophorum angustifolium	.04
Pedicularis groenlandica	.3	Silene acaulis	.04
Erigeron speciosus	.3	Diapensia lapponica	.02
**Hedysarum sulphurescens	.3	Epilobium angustifolium	.02
Arabis nuttallii	.3	Luzula spp.	.02
Valeriana edulis	.3	Luzula tundricola	.02
Pedicularis spp.	.2	Loiseluria procumbens	.02
Dodecatheon spp.	.2	Lycopodium spp.	.02
**Anemone multifida	.2	Rhododendron lapponicum	.02
Polygonum bistortoides	.2	Rubus chaememorus	.02
**Calamagrostis rubescens	.2	Saussurea viscida	.02
**Galium boreale	.2	Galium boreale	.05
Solidago multiradiata	.1	Spirea beauverdiana	.02
Besseya wyomingensis	.1		
Veronica spp.	.1		
Cirsium scariosum	.1		
Ribes spp.	.1		
**Salix spp.	.1	Unidentified Salix spp.	2.53
Lomatium cous	.1		
Poa spp.	.1		
Fragaria virginiana	.1		
Hieracium spp.	.1		
Pedicularis contorta	.1		
Phyllodoce spp.	.1		
Penstemon ellipticus	.1		
Juniperus communis	.1		
Delphinium bicolor	.1		
Lloydia serotina	.1		
Cardamine rupicola	.1		
**Claytonia lanceolata	.1	Claytonia acutifolia	.02
Physaria didymocarpa	.1		
Arabis spp.	.1		
**Saxifraga spp.	.1	Saxifraga hirculus	.02
Polygonum viviparum	.1	Saxifraga oppositifolia	.05
Senecio integerrimus	.1		
Hackelia micrantha	.1		
**Potentilla gracilis	.1		
Total	100.1	Total	100.06
		Shrub Layer	
		Alnus crispa	25.64
		Betula nana	17.95
		Salix alaxensis	5.13
		Salix glauca	2.56
		Salix planifolia	35.90
		Unidentified Salix spp.	12.82
		Total	100.00

* Species that appeared in both Montana and Alaska (excluding trace species).
** Genera that appeared in both Montana and Alaska (excluding trace species).

in both areas were also found. For example, Hedysarum alpinum comprised 0.2 percent of the vegetative cover in Alaska, whereas H. sulfurescens and H. occidentale together comprised 1.9 percent in Montana.

A comparison of all bear food plants shows the alpine meadow complex in Montana to have a bear food plant abundance twice that of its Alaskan counterpart. The greater amount of bare ground in the Montana alpine meadow study plots, however, means that if overall ground cover is calculated, the percentages are closer: 22.2 percent in Alaska versus 36.9 percent in Montana.

	Alaska	Montana
Percent vegetation cover	22.7	51.6
Average ground cover	22.2	36.9

Comparisons of total bear food plant abundance (percent vegetative cover) indicate general habitat quality. More specific comparisons can be made by comparing the abundance of high-preference foods. For example, in alpine tundra/meadow, Claytonia lanceolata (0.01 percent) versus C. acutifolia and C. sarmentosa (0.02 percent together in Alaska); Oxytropis campestris (1.9 percent) versus O. nigrescens (0.05 percent in Alaska); Vaccinium scoparium (1.4 percent) versus V. uliginosum and V. vitis-idaea (6.9 percent together in Alaska). Since food plant species vary greatly in nutritional value, biomass, preference value, and seasonal occurrence, a rating system should be developed to make across-the-board comparisons between ecosystems; however, these examples should illustrate the potential for comparing grizzly bear habitat on a species-by-species or a plant-community-by-plant-community basis between similar ecosystems.

Standardization

As the previous examples illustrate, comparisons between ecosystems require standardized procedures and techniques. Comparisons can focus on differences or on similarities. To analyze these quantitatively, it is necessary to map both ecosystems on a common scale and with similar techniques. The Landsat pixel provides the unit of measurement, the spectral signature provides the mapping technique, and the digital image analyzer provides the means of integrating the two.

Whether vegetation classifications and maps generated from digitized imagery have useful interpretive and comparative value for wildlife management purposes depends on additional standardized ground-truthing of which the most important element is a hierarchical vegetation classification. The various classification levels from series to plant community differ in the two hierarchical classifications discussed. The ecological land type (ELT), ecological land unit (ELU), and forest habitat type (FHT) used to describe groups of plant communities in Montana have no counterpart in the Alaskan classification system. Also the latter system applies to the entire state of Alaska, whereas the Montana classification is largely confined to western Montana, although it has application in adjoining mountain areas. Both classifications are still incomplete, and both will require updating and alterations as ecological and botanical knowledge increases.

To repeat, the most meaningful comparisons from an ecological standpoint can be made by comparing vegetation complexes, plant communities, and species. The Alaska data have been grouped into plant communities, each sample plot yielding one data point. The data from the Montana study will soon be grouped in this fashion, forming a common standard for the community and species levels.

An example of the type of plant community statistics that can be developed is shown in table 4. In the alpine tundra complex in Alaska, Dryas octopetala (Droc) communities comprised 28.6 percent of the ground cover sampled and the D. integrifolia (Drin) community comprised 12.5 percent. Vaccinium (Vavi and Vacspp) communities comprised 12.5 percent, and the Equisetum arvense (Eqar) community comprised 14.3 percent.

Table 4.--Northwestern Alaska alpine tundra complex-plant communities

Plant Community	Number of Plots	Percent
Erra-Cabi-Lepa-Vavi	3	5.4
Cabi	4	7.1
Cabi-Bena	4	7.1
Eqar	8	14.3
Cabi-Drin	3	5.4
Drin-Sare-Cabi	4	7.1
Vacspp-Lepa-Emni-Aral	5	8.9
Cabi-Droc	3	5.4
Droc-Case	5	8.9
Droc	2	3.6
Droc-Aral	2	3.6
Droc-Cate	4	7.1
Bena-Vacspp-Emni	2	3.6
Cate	1	1.8
Sare-Salspp/Eqar	4	7.1
Lichen	2	3.6
Total	56	100.0

DISCUSSION

Landsat multispectral imagery in conjunction with vegetation sampling and computer assistance provides a definitive vegetation mapping system based on ecological principles and ecological hierarchical classifications. The system can be applied at the ecosystem level to map, quantify, and analyze vegetation categories within a specified biogeographical area or to compare various plant categories between ecosystems. Ecological classifications as extensive as the

series or as small as plant community groups can be computer-mapped and quantitative, descriptive data can be extracted by computer. Site-specific field data on plant utilization can be manually or electronically entered into the system and such data analyzed in context with area statistics for all or any portion of a given ecosystem. Both the imagery and the data base can be continuously updated.

For the system to become a routine tool in the management of wilderness resources, it will be necessary to do the following.

1. Develop and or complete hierarchical vegetation classification systems for extensive geographic areas (these should include vegetation classes ranging from the series to the plant community).
2. Standardize vegetation field sampling procedures to establish comparable descriptive data bases.
3. Standardize, within the limits of current computer capability, a color-code classification for the vegetation categories high on the hierarchical vegetation classification (for example, shades of green for forest complexes, violet for shrublands, yellow for grasslands.
4. Develop specific botanical and ecological criteria for delineating ecosystems or biogeographical areas (this will improve the accuracy of extrapolation).
5. Standardize terminology wherever possible.

Basing grizzly bear management on population data has been largely unproductive and often highly controversial. It is now possible for wildlife managers to begin managing grizzlies on an ecosystem level through better understanding their ecosystem habitat requirements. The wildlife profession is on the threshold of obtaining a wider view: a satellite window. If the vegetation of an ecosystem can be accurately mapped and quantitatively described (Craighead and others 1982), the next obvious step is to map and compare ecosystems. This is now possible and should open areas of inquiry to plant ecologists and offer numerous advantages to wildlife managers.

Enough is known about the food and habitat requirements of grizzly bears to make it possible to interpret this knowledge in terms of the total area of critical habitat available within an ecosystem, the size and distribution of bear activity centers, food plant abundance, and ultimately carrying capacity. It should be possible to make precise and objective comparisons between the Yellowstone Ecosystem, the Bob Marshall Wilderness, Glacier, and the Selway/ Bitterroot, and also to make more meaningful comparisons between bear habitat in Montana and Alaska. By integrating (through specific modeling) cumulative effects with a highly definitive vegetation data base (Christensen and others 1984; Winn and others 1984), it should be possible to predict what wilderness uses will be compatible with a viable grizzly population and obtain a better understanding of the population levels that should be maintainable in any given biogeographical area. With such information obtainable goals can be set, the progress of recovery programs can be judged, and questions confronting policy makers can be asked. For example, where should grizzly bears be perpetuated? How much and what kind of terrain is required? Can a wilderness habitat core support a viable population, or are adjoining multiple use lands essential? What is the optimum bear density for a specific biogeographic area or portion of it? How does bear density compare between ecosystems? What types of information are applicable to more than one ecosystem? How can such knowledge reduce duplication of effort in bear research projects? Finally, what specifically can be done to improve grizzly bear recovery plans and management procedures with comparative ecosystems data?

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HABITAT SELECTION IN THE BROWN BEAR IN EASTERN FINLAND

Erkki Pulliainen

ABSTRACT: Forty-one brown bear den sites studied in eastern and northern Finland indicate that forests are the most important overwintering areas. Ninety-four stomach analyses showed that animal matter is important from May through July; the importance of plant matter increases toward late summer. During the first half of the summer, bears may be attracted to artificial feeding sites where meat is offered. Berries of Vaccinium myrtillus, Empetrum nigrum, Rubus chamaemorus, and Oxycoccus quadripetalus are decisive in determining habitat selection in late summer. If the bears are not disturbed, habitat selection may not be affected by the presence of humans.

INTRODUCTION

In Finland the brown bear (Ursus arctos L.), which is a close relative of the North American grizzly bear (Ursus horribilis horribilis Ord), spends about half the year in a dormant state and spends the rest of the year recovering from the "stress" of the previous overwintering and preparing for the next dormancy period. This omnivorous carnivore has two or three essential habitats surrounding its winter den and the places where it obtains its food during early and late summer.

This study of brown bear habitat selection is based on recordings of den sites, analyses of stomach contents, direct observations of feeding bears, and observations of the recolonization of Finland by bears.

MATERIAL AND METHODS

The research team analyzed stomach contents of the 47 brown bears killed in eastern and northern Finland from May through July and those of 47 bears killed from August through October. We observed feeding bears at natural and artificial feeding sites in this area and studied 41 den sites.

From 1977 to 1981, the Finnish Border Patrol Establishment systematically recorded crossings of brown bears along the 2 574-km frontier. The wanderings of the migrating bears were followed in inland areas and compared with those of migrating wolves (Canis lupus L.).

RESULTS

A summary of den site locations (table 1) suggests that bears select coniferous forests or forests containing conifers to overwinter in. It became evident during the field work, especially in eastern Lapland and northern Finland, that brown bears had difficulties digging in the ground due to its stony consistency (Pulliainen 1974). The dens were covered by a thick layer of snow during the winter.

Table 1.--Location of brown bear den sites in Finland

Site	Number	Percent
Under roots of a conifer	11	26.8
Dug into an ant hill	11	26.8
Under a big boulder or between several boulders	9	22.0
Under the crown of a fallen conifer	3	7.3
Dug into the ground	3	7.3
Under the lower branches of a spruce	2	4.9
In a rock cave	2	4.9
Total	41	100.0

Food

Figure 1 shows the frequency with which major food items are found in the stomachs of the bears studied. The percentages of ungulate protein, ants, and other insects are conspicuously high from May through July. During this period, berries, roots, and other plant matter are of minor importance. Once the berries have ripened in August, they become important diet items. In the southern part of the study area, oats and other available cereals were similarly utilized by the bears.

Paper prepared for the Grizzly Bear Habitat Symposium, Missoula, MT, April 30-May 2, 1985.

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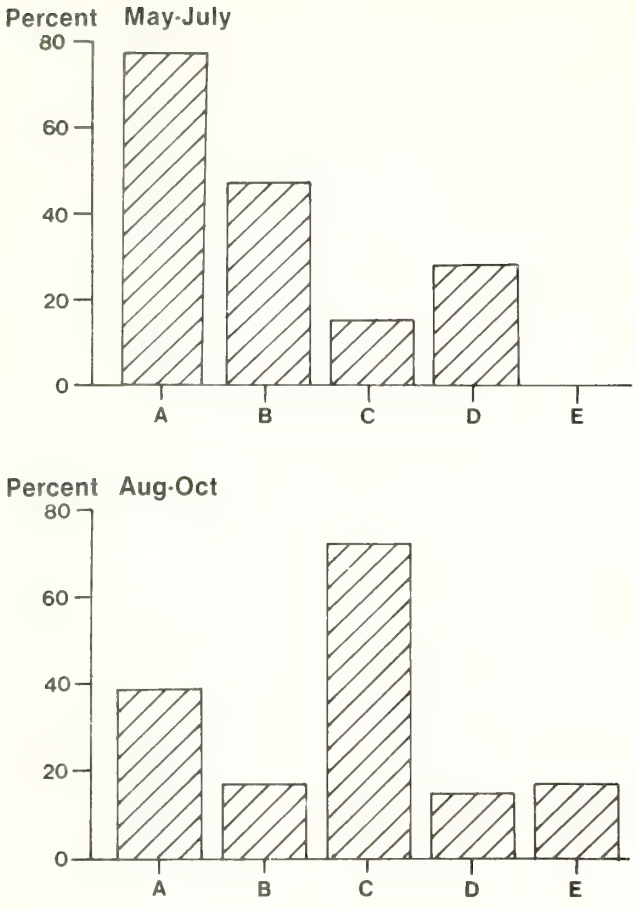


Figure 1.--Food of the brown bear from May to July (n = 47) and August to October (n = 47) according to stomach analyses. A = flesh of large mammals; B = ants, insects, and so on; C = berries (Vaccinium myrtillus, Empetrum nigrum, Rubus chamaemorus, and Oxycoccus quadripetalus); D = roots and other vegetable matter; and E = cereals (oats).

During the first half of the summer, up to mid-July, the research team put out meat, fish, and other animal matter at a feeding site near the eastern frontier, which attracted a varying number of bears (for details, see Pulliainen and others 1984; Pulliainen 1984). At these feeding sites they observed a social hierarchy among bears, with older males being dominant (Pulliainen and others 1984).

Behavior of Recolonizing Bears

During the 1970's and early 1980's, bears immigrated into Finnish Northern Karelia, Kainuu, and Koillismaa, Finland, from the saturated Soviet Karelian population. Some individual bears moved into the inland areas of Finland, crossing the whole country from east to west (Pulliainen 1983) (fig. 2). There were several occasions when restless bears from wild uninhabited areas settled areas of eastern Finland. Later, the same individuals or others, if not actively disturbed,

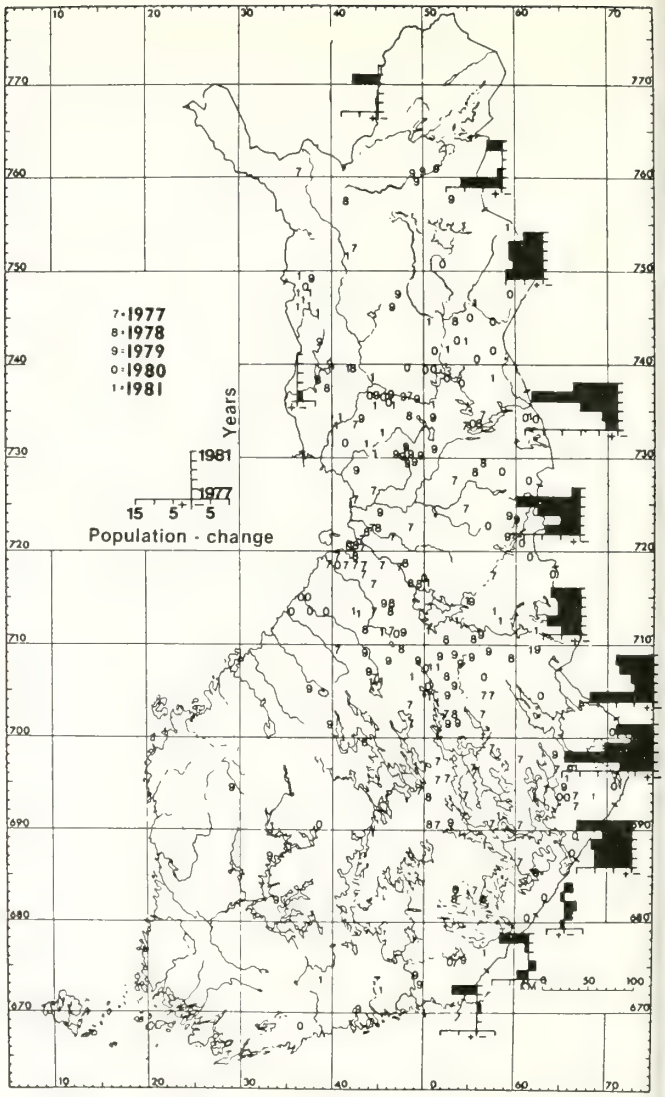


Figure 2.--Numbers of immigrating and emigrating brown bears along the Finnish border and one yearly occurrence of bears within the inland area. As reported by the Finnish Border Patrol Establishment newspaper, and other public information sources.

moved into the vicinity of southern coastal human settlements.

DISCUSSION

Bears consume their annual food needs during 6 months of the year, and thus the availability of these seasonal food resources plays a decisive role in their lives. The omnivorous nature of the grizzly helps it overcome the problem of varying food availability.

The brown bears in Finland experience seasonal extremes of food availability: in spring food is scarce but may be abundant in late summer. Food resources are generally more abundant in the southern part of the country.

Under difficult spring conditions cervid carcasses are assumed to be a highly desirable food item and a concentrated source of nutrition. Danilov (1983) studied the diet of bears beyond the eastern frontier of Finland and reported that ungulates constituted 4.6 percent of their diet in the Leningrad region, 13.1 percent in Karelia, and in the most northerly area of Kola Peninsula, 20 percent. Probably due to availability and possibly to food requirements (Landers and others 1980), animal matter was the most frequently occurring food from May through July in the present case (fig. 1). During the same period, bears may be attracted to artificial feeding sites (Pulliainen and others 1984; Pulliainen 1984).

As for habitat selection, bears tend to find their way in the first half of the summer to habitats where ungulates, their carcasses, or acceptable plants are available. The habitats where the snow first melts in the spring are important and offer food for both ungulates and bears. During the latter half of the summer, habitats producing berries such as Vaccinium myrtillus, Empetrum nigrum, Rubus chamaemorus, and Oxycoccus quadripetalus are essential. Vaccinium myrtillus grows mainly in forests; the other species occur in more or less open habitats. The last two species grow on marshy sites, many of which are now being drained in Finland and thus are becoming rare.

The seeking of shelter is another ecological factor that may govern habitat selection in the brown bear. Humans are the only significant predators on this species in Finland, and bears that have migrated into Finland from the east are moving from wild areas, where they are seldom, if ever, faced with human beings, into settled areas. Thus the rapid movement of bears from one area to another during the recent expansion from the east has been construed as an expression of their avoidance of humans. The immigration and emigration of bears along the Finnish border is summarized in figure 2. For each reporting area the horizontal axis represents the population change associated with the years indicated on the vertical axis. For the same period a yearly numerical code depicts the locations of inland bears as reported by newspapers and other public information services. On the other hand, those bears that have wandered to the southern coast area and stayed have settled in fairly populated areas (fig. 2). This observation indicates that they may become accustomed to human beings who do not harm them.

It has become evident during the recent recolonization of Finland by bears and wolves that there is a certain difference in habitat selection between these two species. Wolves use specific migration routes during their wanderings (Pulliainen 1980)--often ridges or other terrain where it is easy to move. This habit often leads them onto highways, where they are killed in traffic accidents; the bears move more or less directly through forested areas and only one has died in traffic accidents in Finland so far.

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INDUSTRIAL AND AGRICULTURAL INCURSION INTO GRIZZLY BEAR HABITAT: THE ALBERTA STORY

Brian L. Horejsi

ABSTRACT: Agriculture, logging, and oil and gas exploration and development have recently made rapid inroads into grizzly bear habitat in the South Wapiti region of Alberta. The present administration has not instituted compensatory management programs. Hunting, through vastly improved access, has affected the population of marked bears. Until there are major changes in the attitude and actions of elected governments and land management agencies, bear habitat will continue to shrink. Populations can be expected to decline in response, leading to insular populations centered in our national parks. Necessary changes in philosophy and management are listed.

INTRODUCTION

A recent article about grizzly bears (*Ursus arctos*) in the United States indicated that grizzly populations in Canada were secure (Turbak 1984). In fact, not all Canadian populations are secure. Grizzly populations in south and central Alberta are being disregarded by an increasingly antiwildlife provincial administration that has allowed intensive development pressures from three industries--agriculture, logging, and oil and gas exploration and development--without compensatory management. This paper presents illustrative data from an area roughly 40 km southwest of Grande Prairie, AB (fig. 1).

The study area is known as the South Wapiti. It is an area of extensive pine-spruce upland forests and aspen-shrub-conifer mixed forest in the lowlands. The South Wapiti ecosystem lies within two administrative land use zones--the green and yellow zones. This zoning, established in 1948 and at least partially based on land capabilities, was to define the limits to agricultural and residential development; the green zone being the area in which such developments were prohibited. In the yellow zone, agricultural and residential development was to be permitted provided the land was not required for conservation, forestry, recreation, or wildlife habitat. The study area lies entirely within the green zone, administered by the Alberta Forest Service, but is bordered on the immediate north by the yellow zone, administered by the Public Lands Division.

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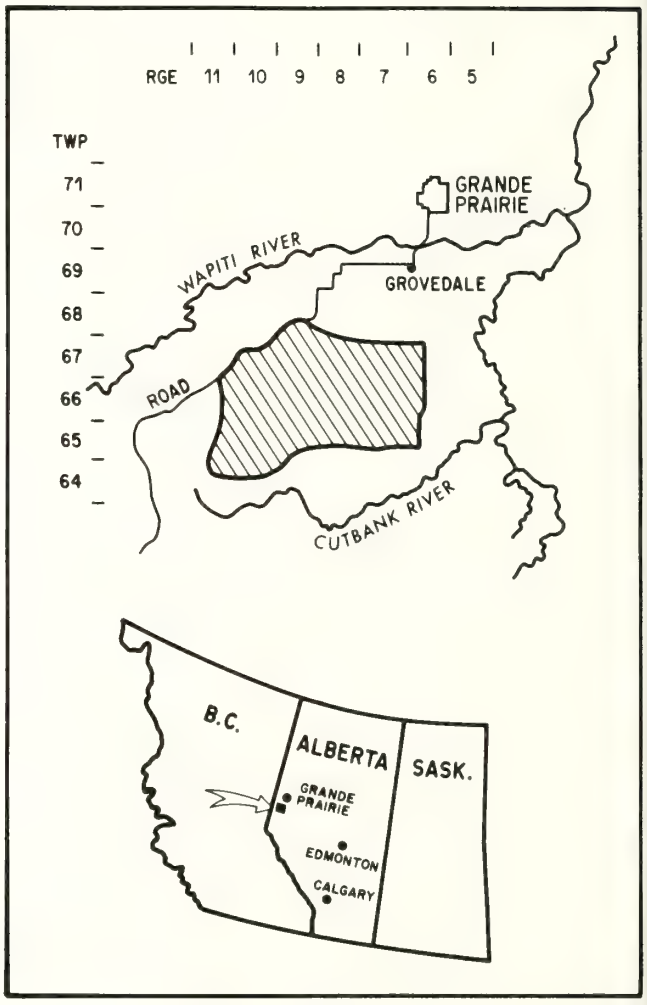


Figure 1.--Location of the South Wapiti study area.

In 1969 the provincial government signed a Forest Management Agreement (FMA) concerning lands in the study area. In 1978 an extensive and rich natural gas field was discovered underlying the area, and it is toward the South Wapiti that human habitation and agricultural activities are creeping. The impact of these three types of activity are herein addressed by documenting the changes that have occurred recently, presenting data on the marked grizzly bear population, and suggesting some remedies.

POLITICAL CLIMATE: A HABITAT PARAMETER

Although there exists a clear separation in conservation philosophy between most biologists and

the politicians and senior administrators they work for, the role of most biologists in Alberta is to facilitate the actions of specific interest groups. They can act, therefore, only within very narrow limits, those limits being set by elected members of government. These limits can only be broadened by public education, public participation, and public activism.

In Alberta the prospects for wildlife conservation are extremely limited. This is not a narrowly held view. In 1984 a questionnaire was circulated to 150 residents of Grande Prairie and area; of 80 respondents, 51 provided a yes or no answer to the question, do you think our politicians care what happens to grizzly bears? Eighty percent said no!

Alberta does not have the advantage of large tracts of federal land or an Endangered Species Act to encourage wise bear management. We do not have the exceptional wilderness system, with prospects for its expansion (Edwards 1985), found in the United States. A policy that provided limited protection for grizzly bear habitat, the East Slopes Policy of 1977 (Alberta Energy and Natural Resources 1977), has been struck down by a Revised East Slopes Policy (Alberta Energy and Natural Resources 1984a). The East Slopes consist of a narrow strip of foothill and mountainous public land on the western edge of Alberta on which most of the Province's grizzly bears are found. The philosophy of the present administration is evident from the thrust of the revised policy, which states that:

1. "Resources extraction objectives such as those of trapping, logging, domestic (stock) grazing, petroleum, natural gas, coal, and mineral exploration and development may be achieved" in critical wildlife zones.
2. "The sale of parcels of public land for permanent and seasonal residential use may be considered."
3. "To expand domestic livestock grazing opportunities on public lands" is an objective in the area that includes the South Wapiti.
4. Should anyone wish to use public land in an area or a way that is presently not permitted, a request for a zoning change can be made.

Before eliminating the East Slopes Policy as an instrument for wildlife and land conservation, the Lougheed administration proceeded with public hearings into the expansion of agricultural lands in Alberta. This thrust has been incorporated into Integrated Resource Management Plans (IMP), the vehicles through which the Revised East Slopes Policy will be implemented. Such a plan is the Sturgeon Lake-Puskwaskau East IMP (Alberta Energy and Natural Resources 1984b), which affects lands that border the South Wapiti ecosystem on the northeast. Under this plan there will be a net transfer of 190 sections of land from the semiprotected green zone to the development-oriented yellow zone. The report states that "about 210 sections (54 000 ha) of high quality (wildlife) habitat will be lost to agricultural development." In addition to these settlement-cultivation losses, alternative lands will have to be found for displaced grazing rights. Such lands will come from the public land-wildlife habitat pool, creating an impact far beyond the original development. Immediately north of the South Wapiti study area, where land is increasingly being transferred from public to private ownership, the "greatest limitation to substantial expansion" of agricultural activity is viewed as being the green zone boundary (South Peace Regional Planning Commission 1984).

The administration in Alberta has taken calculated steps to reduce the effectiveness of the Fish and Wildlife Division through staff reductions. In one district office where three people were present in 1980, there was only one in 1984. That office, in a 15-month period in 1980-81, received 609 applications for construction of oil and gas leases, access roads, and pipelines. During an 11-month period in 1984-85 the number of applications received was 528. On a monthly basis the number of applications to be reviewed rose from 15 to 48 for the single person present. Wildlife considerations were obviously much more superficially treated in 1984 than in 1981.

Wildlife research has also suffered in Alberta; three studies of grizzly bear populations under way in 1981 on Provincial lands had all been terminated by April 1985. Two were terminated prematurely by the Provincial government, with no plans for data analysis or reports.

RESULTS AND DISCUSSION

Agricultural Activity

In 1983 the Provincial government announced a plan for, and held hearings concerning, an expected million-square-kilometer expansion of the yellow zone. Such an ambitious scheme presents an extremely serious threat to the South Wapiti grizzly bear population. Even before the results of the hearings allow or deny a chance to alter green zone-yellow zone boundaries, there have been significant land use changes within the existing zones--changes already harmful to the grizzly.

The yellow zone on the northern edge of the study area (Township 69 and north) was originally all public land and all grizzly bear range. Agriculture has been identified as a factor impacting wildlife lands historically (Brown 1985; McCrory and Herrero 1982), and such is the case in the Grovedale area (fig. 1), where agriculture began in the 1930's. It is somewhat surprising, though, that the majority of agricultural expansion occurred not a long time ago but within the last 15 years. The transfer of grizzly habitat to private ownership skyrocketed in the 1970's, when 48 percent of all the land ever to come into private ownership in the study area was lost to government control (fig. 2) and, coincidentally, to grizzly bears. With those rapid changes in land control came a 213 percent increase in human population; where 258 people resided in 1961, 854 lived in 1982 (South Peace Regional Planning Commission 1984).

In the mid-1960's an even more serious threat to grizzly bears developed. Two grazing leases were established in the green zone, one in the heart of the study area and one to the northeast.

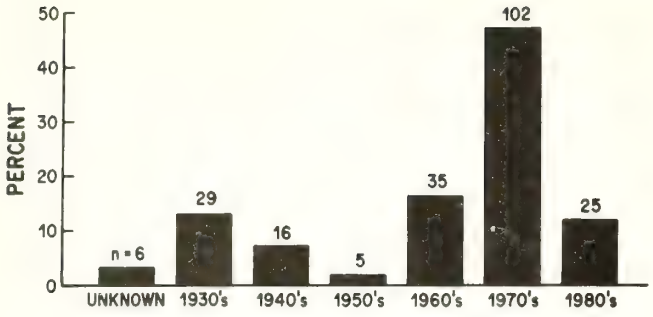


Figure 2.--Periods during which 218 quarter sections of land (former grizzly bear habitat) transferred from crown (government) to private ownership in Ranges 7, 8, and 9 east of Grovedale and south of the Wapiti River. Data include part of 1984.

The Stony Creek lease was issued in 1966 and covered 735 ha in the middle of grizzly bear habitat, an area where no cattle had grazed before 1966. The lease was expanded to cover 1 093 ha in 1970 and remains roughly that size in 1985. The leasee has made application to improve the range, through vegetation modification, and is to fence the area. In 1984 the Alberta Forest Service attempted to cancel the lease by offering three alternate areas outside of grizzly bear range, but the leasee has refused to move. The Forest Service has been forced to relent.

The fate of the wolf (*Canis lupus*) in the lease area can be used to predict the grizzly bear's future. As a consequence of the leasee's depredation problems, real or otherwise, 29 wolves were removed from the lease area between 1974 and 1977. Grizzly bears, too, will kill livestock, whether sheep or cattle (Knight and Judd 1983; Jorgensen 1983). Even though Knight and Judd believe cattle and grizzly bears can coexist "if cattle owners are willing to absorb losses," such tolerance is rare (McCrory and Herrero 1982) and cannot be relied upon.

The two-pronged agricultural threat, first of grazing leases and the subsequent demand for stock protection, and second, the clearing of land and permanent inhabitation of such areas, is a far more serious threat to grizzly bear populations than is the threat of logging or oil and gas exploration. Agricultural development is permanent; people gain control and ownership of the land. They subsequently become protective of their land and property, including stock, and usually want the area biologically sanitized, meaning no bears. This leads to a decline in grizzly bear range and range quality, and then, when private ownership of land is extensive, the disappearance of bears ensues (Elgmork 1976).

Logging Activity

In 1969 the Provincial government signed a forest management agreement with Proctor and Gamble Cellulose Ltd. (P&G) that gave the company exclusive rights to all the timber on an area of 15 285 km². This immense area includes the study area and most of the range of grizzly bears that occupy the study area.

The rights granted to P&G are largely equivalent to those of private ownership. The Alberta Forest Service administers the agreement, with their responsibility being primarily to ensure that P&G removes all timber from the area regardless of the quality of that product. This narrow interpretation forces P&G to harvest areas uneconomical or unattractive to it when such areas could best be used as islands of wildlife habitat.

The forest management agreement in question has no provision for wildlife management input. To incorporate its concerns, the Fish and Wildlife Division can at best hope that P&G and the Forest Service will grant them some concessions. In reality, the Forest Service often acts as a consultant for the company, assisting their interests over those of wildlife and the public.

The management agreement comes up for review every 5 years, and by continually expressing concerns and making inquiries, fish and wildlife biologists at the field level have managed to comment on P&G's timber harvest plans. They have also begun direct negotiations with the company. It has proven impossible, however, to appreciably alter logging activities or forest management area boundaries so as to protect sizable tracts of habitat for grizzly bears and other species.

Although logging has occurred in much of the South Wapiti ecosystem, it has only recently begun to encroach on the study area (fig. 3.); the majority of cuts within the area proper have taken place

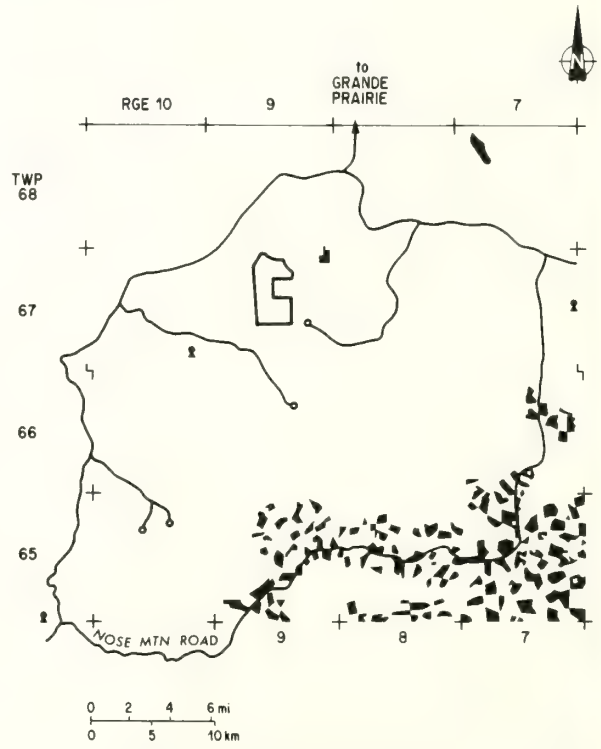


Figure 3.--The location of clearcuts (■) in the South Wapiti area.

since 1983. Four townships that overlap the southeast corner of the study area have had 781, 1 645, 2 185, and 3 629 ha logged, representing 8, 18, 23, and 39 percent respectively, of the area of those townships.

On the positive side, clearcut size declined from the 1970's to the 1980's. The mean size of clearcuts in the 1970's was 59 ha (n= 28), but this has been reduced to a mean of 46 ha (n= 48) in the 1980's ($p \leq 0.02$), a trend that should be encouraged and for which regional biologists and P&G should be congratulated.

As ominous as this extensive clearcutting may seem, there is still less cause for concern about logging than about agriculture. On the basis of my work, the most harmful aspect of clearcutting in the South Wapiti is the provision of access. Excepting main haul roads, the situation is short term, as the roads deteriorate quickly and are allowed to do so. Unlike agriculture, the human presence during logging is short term--the trees are taken, and the area can be abandoned, excluding regeneration activity. Road closures and reclamation would further improve this situation.

It is even possible that, in areas of extensive and dense forest cover, limited and judicious opening of the canopy may prove beneficial to the grizzly bear. Preliminary indications are that such areas will be used by grizzlies *if* human disturbance is absent (Jonkel 1982; Zager and others 1983). Our data (Horejsi and Hornbeck 1984) indicate likewise--that bears will use clearcuts, in the absence of human activity, particularly when regeneration is high enough to obscure a bear. The question remains unanswered, however, as to how the grizzly bear in the South Wapiti would do in a habitat liberally dissected by clearcuts, versus how it would do in the still largely uncut forest.

If competition exists between black bears and grizzly bears, then the removal of forest cover may confer a competitive advantage on grizzly bears (Jonkel 1985). In the South Wapiti area, where both bears are common, clearcutting in the absence of other influences may tip the odds in favor of the grizzly bear. In such a situation, management emphasis must be placed on the control of access and human activity, including hunting.

Oil and Gas Activity

The oil and gas industry is a major contributor to the economy of Alberta. An average of over 5,000 holes per year are drilled in the Province.

Exploration for gas and oil in the South Wapiti began to flourish in 1978 (fig. 4). Drilling required access roads, and during the boom of 1978 through 1981, the yearly pattern of kilometers of road built (fig. 5) mirrored almost exactly the pattern of the number of wells drilled. Grizzly habitat quality, particularly the security aspect of habitat, changed in response. Figure 6 shows the South Wapiti as a relative wilderness in 1969, in stark contrast to figure 7, which shows the

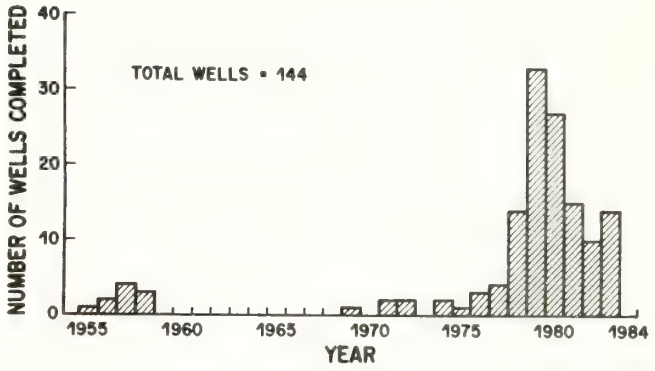


Figure 4.--The number of wells drilled in the study area (Townships 65-68, Ranges 7-11, W6M), 1955 to 1984.

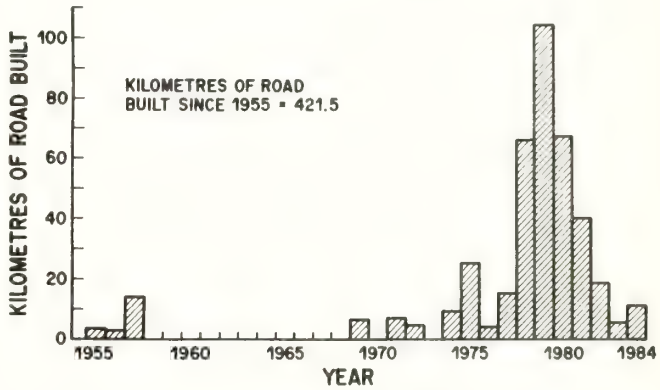


Figure 5.--Kilometers of road built in the course of oil and gas exploration in the South Wapiti (Townships 65-68, Ranges 7-11, W6M), 1955 to 1984.

massive dissection of the area by roads built for resource exploration and extraction.

Few areas escaped the impact of road building and well drilling (table 1). This even distribution of activities came about as a consequence of government policy that provides tax incentives when a gas well is drilled at least 4.8 km away from any existing well. Such policy was designed, with no regard for the wildlife resource, to force exploration companies to expand their zone of exploration, and it has been very successful in achieving that end.

As a consequence of legally defined well-spacing requirements, drilling for gas will have less impact on bears and bear habitat than will drilling for oil. It is technically easier to "drain" a gas field than an oil field; thus gas wells are allowed at a density of one per square mile, whereas oil wells may be permitted at a density as great as 16 per square mile. Such a situation occurs in Township 67 Range 8 (table 1; see also fig. 7), where a shallow oil field is being exploited by Canada's national oil and gas company, Petro Canada.

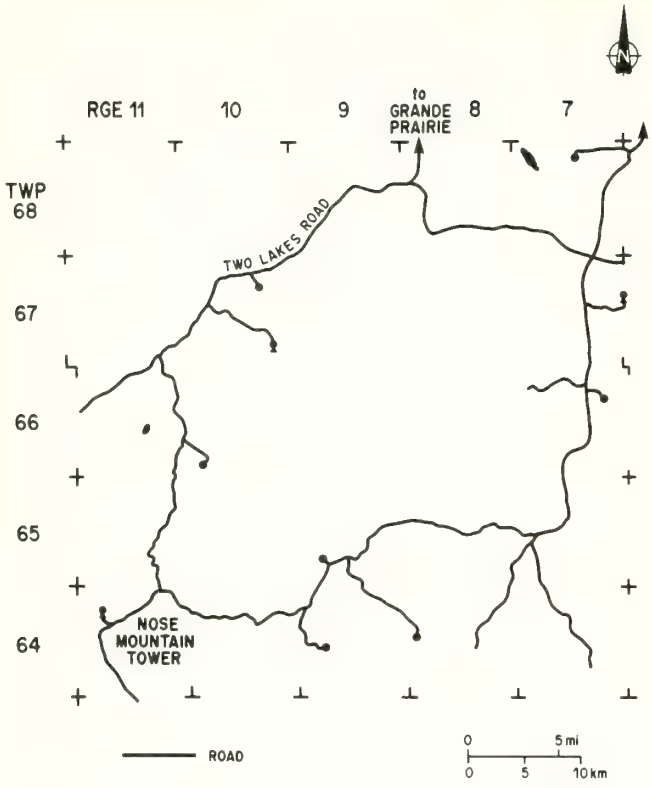


Figure 6.--The South Wapiti area showing roads present at the end of 1969.

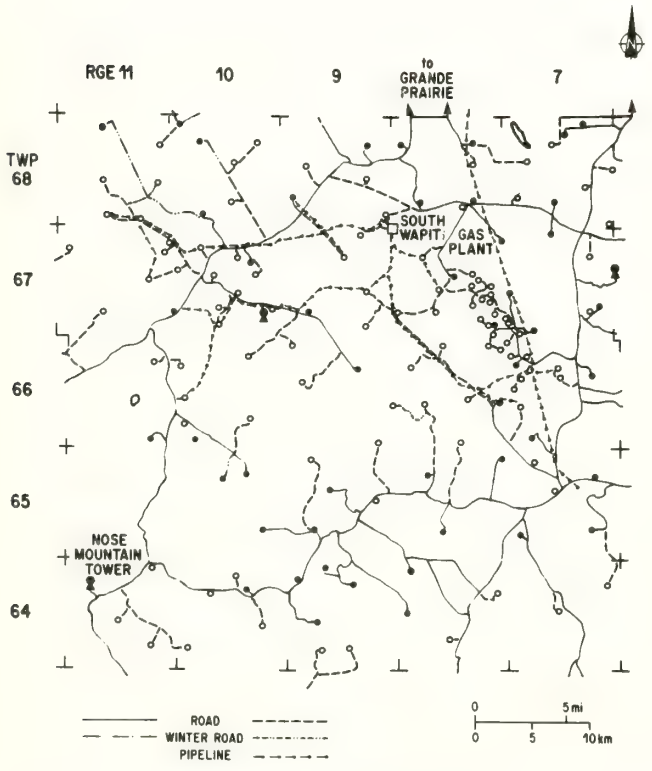


Figure 7.--The South Wapiti area showing roads and pipelines present as of January 1985.

Table 1.--Distribution of wells drilled in the South Wapiti study area (Townships 64-68, Ranges 7-11 W6M) between 1955 and January 1985

Township	Range					Total
	11	10	9	8	7	
68	6	6	5	6	10	33
67	5	10	5	18	9	47
66	2	5	5	8	10	30
65	0	3	4	3	5	15
64	3	4	6	4	2	19
Total	16	28	25	39	36	144

That area has experienced the most intense exploration-development activity in the South Wapiti ecosystem. Petro Canada, whose motto is "for the good of Canadians," has reaped immense benefits from the underground resource but has done nothing to safeguard bear habitat. By their nonparticipation in this grizzly bear study and their refusal of the information generated, they have consciously chosen not to consider the welfare of the grizzly bear population in their drilling and road-building plans.

Drilling activity likely leads to the exclusion of certain bears from certain habitats, the average well in the South Wapiti taking 59 days (n= 144) to drill. The extent of this exclusion, and its impact on a bear, is likely to vary according to the philosophy and actions of the companies involved, the behavior of the people in the field, the intensity of drilling, the nature of the habitat, and the individual bear's behavior.

What we are faced with during the life of a gas or oil field is maintaining a grizzly population at a viable level so that, even if numbers are somewhat reduced, there are enough individuals surviving to permit the population to recover should it become free of the demands of resource development. This is possible if access and hunting are restricted, but the likelihood of such restriction is the crux of the problem. There is an official unwillingness to control access and hunting. The onus is on government, not industry, to do that. Industry can greatly downgrade road standards to winter road status; well head facilities are increasingly being remotely operated by computer; servicing can be done by helicopter. Such changes in operating procedures can reduce access and impacts on wildlife populations, but the onus is on politicians to require the changes. In this respect, Alberta has been negligent.

THE GRIZZLY BEAR POPULATION

This brief discussion of the grizzly bear population in the South Wapiti is restricted to the captured population and available statistics on legal and illegal kills. In 4 years, eight of the 35 bears captured have been killed (fig. 8), and two other bears are unaccounted for.

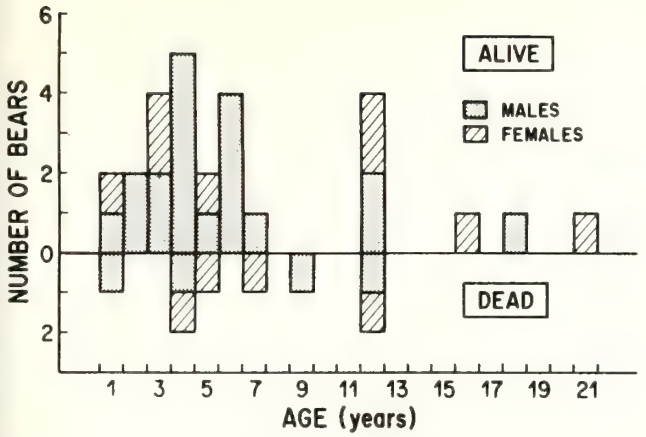


Figure 8.--Age distribution of captured grizzly bears and their young in the South Wapiti area as of November 1984.

At a minimum, this represents an annual mortality rate of 6 percent. More significant is the following: 50 percent of the bears killed were females. Four of the nine females 4 years of age or older have died, an annual mortality rate of 11 percent. The importance of survival among adult females cannot be overstated (Knight and Eberhardt 1984), and it is likely that the high level of mortality among this class of animal in the South Wapiti, if representative of the population at large, exceeds that which would permit the existence of a stable population.

The number of legally registered grizzly bear kills in and around the study area during a recent 6-year period is given in figure 9.

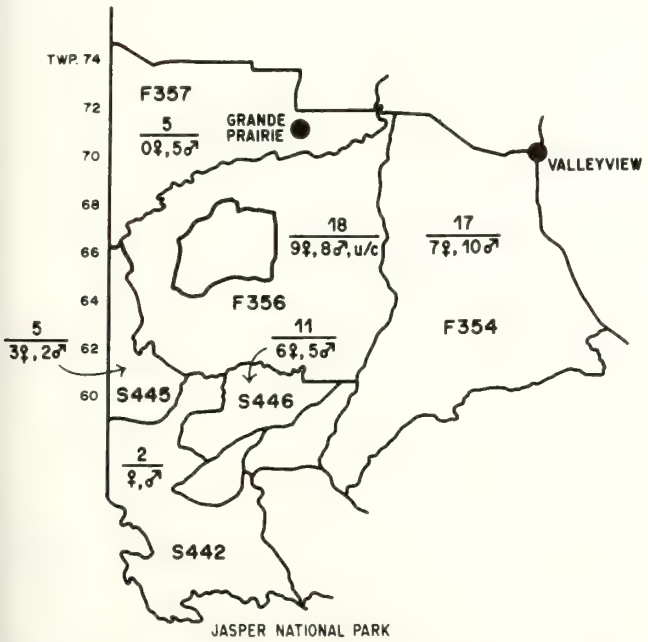


Figure 9.--The number (above line) and sex (below line) of grizzly bears killed in the South Wapiti area, by wildlife management unit (prefix F or S), 1979 to 1984.

Telemetry data (Horejsi and Hornbeck 1984) indicate that the bears caught in the study area range into wildlife management units (WMU's) F357, F356, S445, S442, and S446, as well as adjacent British Columbia. The registered kill of grizzly bears from the South Wapiti populations is 41 animals in 6 years. Nineteen of those bears have been female.

Data from marked animals indicate that three of eight kills (38 percent) were illegal. With this in mind, the legally registered kill can be reexamined. Recognizing that it includes five known illegal kills (three mentioned above, plus at least two others), total human-caused losses can conservatively be estimated at 49 bears (.38 x [41-5]). Illegal kill is, however, likely to be even greater than 38 percent of the legal kill. In addition, the extent of natural mortality is unknown. Total losses to the population, therefore, unquestionably exceed known mortality.

In addition to the effect of improved access on legal and illegal killing of grizzly bears, industrial and agricultural activity creates what could be defined as a deliberate conflict between humans and bears. Among these conflicts, agriculture has the greatest impact on grizzly bears (table 2). In Alberta, it is legal for a landowner or leasee to kill any black bear on land under the individual's control; neither permission nor reporting of kills is required. Given the difficulty understaffed wildlife officers have in responding to complaints, there seems no question that the number of bears reported (table 2) is but a fraction, perhaps one-third to one-half, of those actually removed, all but a few of which are killed.

Table 2.--Number of grizzly and black bears removed from the South Wapiti area (Townships 61-69, Ranges 4-13 W6M) as a consequence of five kinds of human activities, 1977 to 1984. (All removals listed were management actions.[1])

Year	Activity													
	Agri-culture		Logging		Oil and Gas		Admin./ Subdiv.		Recre-ation[2]		Total	
	B[3]	G	B	G	B	G	B	G	B	G	B	G
1977	9		18	1	20		3		5		55	1
1978	4	1	4	1	3				4		15	2
1979	1	1	2		19	[4]1	1		6		29	2
1980	5		6		38		3			1	52	1
1981	1	[5]3	5		5						11	3
1982			4		3						7	0
1983	9		1				1		2		13	0
1984	1		1		2		1		1		6	0
Total	30	5	41	2	90	1	9	0	18	1	188	9

[1]Source: Alberta Fish and Wildlife Division occurrence records.
[2]Management actions associated with recreational facilities.
[3]B = black bear; G = grizzly bear.
[4]Cub sent to zoo.
[5]Female and two cubs relocated 197 km distant.

Has grizzly mortality increased since the increase in accessibility, or are there more bears? The Province of Alberta, in a political analysis of the status of the grizzly, stated that populations declined in the 1960's but have increased since the 1970's (Alberta Energy and Natural Resources 1984c). Unfortunately, no field study of any grizzly bear population on Provincial lands had ever been done before 1974; thus the analysis cannot be substantiated.

The South Wapiti study area is in WMU F356. Access to WMU's F354 and S446 increased dramatically, at the same time and for the same reasons, as it did in F356. In contrast to these areas, F357 is a largely agricultural area with relatively undeveloped perimeters that has seen no significant changes in access for at least 10 years. It is not coincidence that the number of registered grizzly bear kills has about doubled in those management units where access has greatly improved during the last 6 years (fig. 10). Yet the heart of the problem is not simply access but, more precisely, the lack of restrictions on carrying guns and hunting.

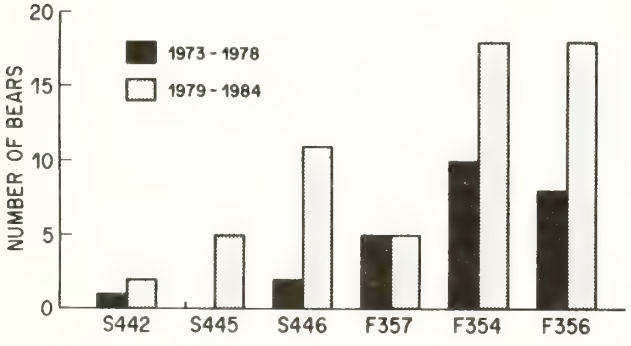


Figure 10.--Number of grizzly bear kills registered during two 6-year periods in Wildlife Management Units in the South Wapiti area.

REMOVING THE THREAT TO GRIZZLY BEAR POPULATIONS

Actions that would help conserve grizzly bear populations can be placed in two categories: long-term solutions and immediate or temporary solutions.

Long-term solutions are, in reality, the only solutions. They include:

1. The establishment, on Provincial land, of an extensive wildlife refuge and wilderness preservation system similar to that found in the United States of America.
2. The establishment of administrative areas where oil and gas exploration and timber harvesting continue but the carrying of weapons is severely restricted and hunting is not permitted.
3. A major change in the mandate of the Alberta Forest Service. Their advocacy role on behalf of forest, oil and gas, and grazing industries must be replaced with the recognition that wildlife values equal, or may exceed, those of other resources. Becoming accountable to all of the people of Alberta will require a massive change of attitude by agency professionals.
4. The development of a political will that recognizes the social, recreational, and ecological values of grizzly bears and thus their need for security and habitat.

Immediate or temporary solutions will extend the life of existing bear populations and will lead to long-term solutions. They include:

1. The development of citizen groups that fervently pursue wildlife conservation through political and public education channels with the assistance of government funding.
2. The cessation of crown land sales.
3. The removal of rights-of-ownership from leased land holders.
4. Government uniformity in the demands made of, and expectations placed upon, industry. Guidelines protecting wildlife and wildlife habitat should be legislated and enforced.
5. A surcharge placed on each exploration and development project on crown land, leases included, amounting to 10 percent of the cost of each program between $50,000 and $5,000,000 (scaled back when larger sums are involved). This money would go into a fund for long-term wildlife monitoring and research programs, with major emphasis on the area affected by exploration. Such a fund would be collected and held by a foundation with funds assigned by a review board of industry biologists, consulting biologists, academics, the public, and government biologist
6. Development of an information and education section in the Fish and Wildlife Division.
7. A major effort to inform individuals who graze cattle on crown land that theirs is a privileged position and that privately owned cattle do not take precedence over publicly owned grizzly bears.
8. Prompt action by the Forest Service, in cooperation with the Fish and Wildlife Division, to completely restrict access in key nonwilderness areas and on all but designated routes in other nonwilderness areas, both during and outside of hunting seasons.
9. Where access for resource extraction is permitted, all but main roads should be kept to winter road standards.
10. Strict regulations and enforcement regarding garbage management should be applied in resource development areas.
11. The elimination of fall grizzly bear hunting in all areas where motorized travel is permitted.
12. Establishment of a kill quota, not to exceed 5 percent of the population, that incorporates legal and illegal kills, whether sport hunting or management related. All grizzly bear hunting licenses should be chosen by draw.
13. The elimination of hunting in at least one out of every three wildlife management units, possibly on a rotating basis.

SUMMATION

Agriculture, logging, and oil and gas exploration have dramatically changed grizzly bear habitat in the South Wapiti. The impact of agriculture, excepting grazing, can be mitigated only in special cases. The impacts of logging and oil and gas activities manifest themselves primarily through access and subsequent hunting pressure. At this time, government has not compensated for these changes with improved management.

Most resource companies are not knowledgeable about wildlife and therefore may be indifferent, if not opposed, to wildlife conservation measures. There are exceptions among corporations, but our present system does not reward them for their exemplary conduct. Their voluntary help and understanding are important and should be recognized. Implementation of the short-term measures previously itemized will slow grizzly habitat and population losses, and they therefore require prompt action. It is not the responsibility of resource companies to make major decisions regarding the management of wildlife resources, but it is their responsibility to demonstrate wise corporate stewardship of wildlife resources by conducting their operations with the interests of that resource in mind and by providing information about the interaction of that resource with company operations.

On the other hand, it is the responsibility of elected government to maintain grizzly bear populations. The government of Alberta has not fully met this responsibility. The absence of compensating management programs for wildlife in today's resource extraction arenas, where there is almost no control of access and little control of hunting, is evidence of its default. Elected and senior appointed officials in Alberta have demonstrated a low regard for public land and wildlife resources.

ACKNOWLEDGMENTS

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GRIZZLY BEAR HABITAT RESEARCH NEEDS IN THE BORDER GRIZZLY AREA

Charles J. Jonkel and David Hadden

ABSTRACT: Needed grizzly bear habitat research has been seriously delayed. The required studies fall into three main categories: further studies in habitat use and habitat relationships; studies that develop and refine existing and additional systems for classifying, mapping, and monitoring existing habitat and habitat changes; new studies on special vegetation topics such as habitat improvement techniques, the growth and development of key bear food plants, disturbance impacts, the development relationships and growth dynamics of key bear food species that thrive on disturbed sites; and the nutritional levels and nutrient extraction of key grizzly foods. Short descriptions, justifications, and the status of needed studies are given; a priority ranking is presented for consideration.

INTRODUCTION

Habitat management is the main key to managing and preserving any wildlife species. Without an adequate data base on habitat relative to individual species, and without the application of habitat management principles relative to that data base, the management of a target wildlife species is impossible. Habitat loss ultimately leads to species loss. Without an adequate habitat, subtle and direct impacts combine to cause the death of individual animals, and reproduction fails to balance death rates. The direct causes are relatively easy to measure and comprehend; indirect losses because of stress, seasonal inadequacy, a degraded nutritional level, behavioral changes, low genetic or behavioral plasticity relative to habitat change, and interspecies competition are difficult to detect and measure. For example, losses of individual grizzly bears (Ursus arctos horribilis Ord) that die from indirect or obscure causes are just as serious as are losses from bear-people conflicts or hunting.

The grizzly requires large ranges to meet its foraging, denning, reproductive, and behavioral needs. The sizes of grizzly bear ranges vary by habitat adequacy (Pearson 1975; Craighead 1976; Jonkel 1982), which in turn varies regionally. Many of the regional variations in habitat adequacy are based on naturally occurring land capabilities; other variations are caused by human activities and change constantly. Habitat management, therefore, must vary regionally, depends upon regional data bases, and must keep abreast of habitat quality changes. To clearly identify regional research needs and guide regional management, one must look at what circumstances exist, identify what we do not know, and set priorities based on management needs.

Management needs are the driving force for research needs, but unfortunately they are greatly influenced by such things as short-term goals and crises, political influences, budget cuts, interagency disputes, and a failure to apply existing data bases. As a result, research direction is often unclear and misdirected, long-term research needs are delayed or interrupted, and effective research vehicles are dismantled or hampered in their function. Grizzly bear habitat research is particularly vulnerable to such upsets because of the high profiles of grizzly research and management and because grizzly bears, grizzly bear research, and grizzly bear management obstruct resource exploitation and require care in resource development. Because grizzlies are long lived, have large range and nutritional needs, and are difficult animals to study, the entire research process suffers excruciating delays, and management gets ahead of research. Because the grizzly has considerable economic and political impacts, the research process is easily subverted and misused. Both the delays and interference in long-term research and the subversion of the research process must cease if grizzly management is to proceed in an orderly manner. A return to sanity in grizzly habitat research is essential to preserve the bear, but that does not ensure that a return to sanity is likely.

The complex of considerations previously cited, plus subjective estimates based on long-term, future outlooks for the grizzly, the status of other bear species' habitats, the political realities of grizzly bear management, and even the impending world-wide human population-resource depletion crunch, must be considered in identifying research needs and priorities. The following list of priorities and justifications provides needed vision; it may help determine long-range research goals for the Border Grizzly Area as well.

NEEDED RESEARCH BY PRIORITY

Disturbed Site Vegetation Studies

According to Border Grizzly Area (BGA) food habits studies (Mace and Jonkel 1983), grizzly bears consume nearly 200 separate plants in the BGA. Only about 30 of the plants are significant food

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sources in any local area, however, and a high percentage of that 30 are "lovers of disturbed sites." Plant species such as glacier lily (Erythronium spp.), Claytonia spp., and Carex spp. proliferate on avalanche chutes; cow parsnip (Heracleum lanatum), Equisetum spp., and Hedysarum spp. are found on creek bottom and river bank or flood plain disturbed sites; and Vaccinium spp. and Amelanchier alnifolia grow abundantly on burns; Hedysarum spp., Lomatium spp., and Erythronium spp. respond to the mechanical disturbance of bears digging for roots and corms; species such as dandelion (Taraxacum spp.), Trifolium spp. (clover), and Angelica spp. readily respond to human mechanical disturbance.

Most impacts relative to grizzly management and survival result from losses caused by excessive habitat disturbance. For example, habitat disturbances such as clearing for agricultural use, subdivisions, or water impoundment cause permanent loss.

However, shorter term disturbances such as timber harvest, road construction, postlogging treatments, revegetation programs, and controlled burns also disturb grizzly bear habitat, but contrary to popular belief, many of the key bear foods can respond favorably to these lesser, human-caused disturbances, provided the disturbance is properly designed. If cover or isolation stay intact, properly designed development need not seriously damage grizzly bear habitat quality. However, the mechanisms for promoting grizzly bear use and favorable growth responses from the key bear food "lovers of disturbed sites" after human-caused disturbances remains poorly studied. Because human-caused impacts will increase, and may either harm or aid bears, this area of research must have the highest priority.

Habitat Improvement Research

Many grizzly bear habitats were inadvertently damaged through past development programs such as the massive clearcutting and 100 percent scarification logging operations of the 1950's and 1960's. Recovery as grizzly habitat or as timber-producing sites has not progressed on many sites. Certain current logging designs and developments also do not respond as expected, adding grizzly bear habitat losses. Other disturbed sites do recover but respond slowly. In all cases, the recovery of such sites could be greatly accelerated if better cutting and post-logging treatment, plus grizzly bear habitat improvement techniques were available. Moreover, wildlife habitat improvement funds are available from timber sales, but our knowledge of how to improve grizzly bear habitat is nearly zero. Long-term, quantitative studies are essential; current habitat improvement study efforts by Ranger District staffs are well intentioned but are short-term and consequently will provide inadequate or erroneous data bases. Considering the enormous additional disturbance impacts to grizzly habitat that are inevitable in the near future as human populations continue to expand rapidly, methods for designing disturbances, improving disturbed sites, and accelerating habitat recovery through the propagation of bear foods and increasing berry or tuber production or other means should be the second highest BGA research priority.

High-Density Grizzly Complexes

Certain areas of occupied grizzly bear habitat offer optimal habitat quality to which grizzly bears readily respond. All elements of the habitat must be intact, such as a superabundance of food within a high diversity of bear food species so that some type of food is available during all successional seasonal stages. Adequate cover or isolation must also be available, and the local bears must make behavioral adaptations if they are to use the site. In such cases, bears in the BGA reach densities as high as one bear/km^2 (Jonkel 1982). Under such circumstances, we have found as many as 40 grizzlies seasonally occupying areas the size of a single grizzly bear home range in the North Fork of the Flathead River. Such high-density areas are known for the East Front, the South and North Forks of the Flathead River, and the Mission Valley.

Management focus obviously should be centered on such high-use, high-density areas. Habitat research emphasis spread equally throughout occupied habitat (the current approach), including areas where the grizzly density may be as low as one bear per several hundred square kilometers, is not logical. Intensive management focus on the high-density sites is imperative; research data bases should be obtained with equal intensity. Careful management of such high-density areas is essential to maintain both habitat and grizzlies; this area of research should rank third in importance for the BGA.

Special Vegetation Studies

Certain key bear food species such as Heracleum lanatum, Claytonia spp., or Lomatium spp. are well-known plants, but their ecological relationships are not clearly understood. They are of little commercial value and are not significantly important to wild or tame ungulates. Consequently, we know little of their growth dynamics, food production, regeneration-reproduction, site preference, and so on. Some such plant species are enormously important to the grizzly, and they deserve intensive research emphasis. Vegetation studies are inexpensive, and some can be short-term. Having data bases on these species is essential before grizzly bear habitat components, bear movements, habitat use, and so on can be adequately analyzed. This area of research should be ranked fourth for the BGA.

Private Land Management Problems

Sixty-three percent of the occupied BGA south of Canada is under U.S. Department of Agriculture, Forest Service, jurisdiction. It follows that lands administered by the Forest Service should

receive a major research and management effort; however, many high-density grizzly complexes are on low elevational sites, often in private, local, corporation, or Indian ownership. These ownerships often have high seasonal densities of grizzlies; critical spring feeding sites and travel corridors are often on them. Bear-people conflicts, too, are centered on such ownerships; law enforcement is essentially impossible on the large blocks of private land; multiple jurisdictions prevail; the U.S. Endangered Species Act of 1973 does not apply directly to habitat; and the implementation of applicable laws occurs indifferently. Moreover, the responsible county, tribal, and soil conservation district governments have almost no motivation or expertise in land or grizzly management and research; most local governments actively follow directions counter to grizzly bear habitat management. Consequently, although the total habitat outside the jurisdiction of government agencies is low, these low-elevational areas are extremely crucial to grizzly survival. Perhaps up to 50 or 60 percent of our grizzly and grizzly habitat management problems occur on these ownerships, even though less than 20 percent of the occupied habitat is involved. It follows directly that research on management methodology is extremely crucial relative to this level of ownership and jurisdiction. Among long-range management goals, this area of research should rank at least fifth.

Grizzly Bear Habitat Use

How grizzlies use their local habitats is essential information for local management program implementation. Certain data bases and data sets can be extrapolated to new areas; many data sets cannot be extrapolated except on a temporary basis. Habitat use patterns change locally as impacts are introduced and altered or as the grizzly's relationships to black bears (Ursus americanus) and humans change. Local bears adapt to their local habitat; habitat use patterns evolve that are unique to that local area and are preserved through "cultural inheritance" passed on by mothers to young. It follows, therefore, that habitat use studies must be repeated locally wherever land use is intensified or altered significantly. Habitat use patterns by the local bears, together with locally designed habitat management, is the ultimate determinant in the survival of local populations. Many local area studies have been completed and some areas are being managed adequately using extrapolated data, but throughout the BGA this research topic is of high importance--at least a rank of sixth and higher in local areas.

Combined Grizzly Bear, Black Bear, and Human Habitat Interactions

Gross population comparisons indicate that grizzly bear habitat can be occupied by grizzlies alone or occupied by a lower number of grizzlies living in a state of habitat competition with black bears and humans (Jonkel and Carriles 1985). Although black bears, humans, and grizzlies can successfully occupy a unit of habitat simultaneously, under many circumstances a population increase by any of the three may affect the possible density level of the other two. Additionally, humans, together with either of the two bear species, can inhibit occupation by or population growth of the other species: if a black bear population is high, the adult male black bears may effectively inhibit the immigration or survival of subadult grizzlies; a high grizzly density apparently can inhibit or sometimes replace a local black bear population. Exact niche differences no doubt exist for people and the two bear species, but when a factor such as nutritional stress increases, the impact of people on bear density must increase. Further, the local stratification or segregation of black and grizzly populations has been noted in the North and South Forks of the Flathead River, in Alaska, and possibly in the Cabinet Mountains and in Yellowstone National Park (Jonkel and Carriles 1985). If such interspecies competition is a serious block to population augmentation, subadult immigration, management, or the occupation of former range, then the design of management measures becomes necessary. These are important considerations relative to the recovery of grizzlies south of Canada, so the topic should rank at least seventh in research priority.

Further Habitat Classification Studies

As land uses intensify, there is a need for further habitat classification and habitat monitoring. The refinements must take two directions: one on a more detailed scale to cope with the design or location of something as small as a bridge or trailhead, the other a broader direction where regional development trends can be addressed or better designed. Land uses, when increased locally in a high-density grizzly bear habitat, call for refinements of the Grizzly Bear Habitat Component (GBHC) technique to the vegetation type or community type level so that more exact bear use and habitat changes can be measured and monitored. Conversely, when management measures are applied to a minimal, broader level (such as an entire valley in a wilderness area), ways of grouping community types or even GBHC's into super components must be devised, or perhaps landsat techniques should be developed and applied.

Community type classification has only begun at the research level, and not all of the research needed for describing GBHC's has been completed. The completion of this research (for example, further classifying GBHC's) should have preceded management application. Any further delays in the research will only result in additional incorrect mapping, and the further waste of mapping funds. This study should rank high, but we relegate it to eighth in priority because other pressing research needs must first catch up.

Land Use Planning, Critical Site, and Conservation Strategy Studies

Land use planning for occupied grizzly habitat is enormously essential, if counterproductive

developments, management programs, implementation procedures, and other undesirable factors are to be controlled. The lack of regional land use planning hurts all sectors of our local economies, our societies, and our resource bases. Sustained development, the key terminology inherent in the World Conservation Strategy (WCS 1980), is equally applicable to grizzly habitat management. It is an approach that has become an absolute necessity in Third World nations where the numbers of people engulf the natural resources. In terms of the grizzly, it includes land use planning, resource development, and the protection of grizzly bear critical sites (high-density areas) simultaneously. It is an economically viable approach; it requires habitat preservation based on the careful planning of sustained resource use.

The methodology of identifying and designing sustained resource use compatible with the maintenance of grizzly bear habitat requires new concepts in ecologically oriented research, combined with economic studies, studies of local political motivations, and the development of communication programs. Critical sites are highly important to bears, but they are also subject to development threats such as subdivisions, timber harvest, and oil and gas development. Ways to sustain local economies while simultaneously maintaining grizzly habitat quality is the challenge of the future and the main goal of this research category. It should have a high priority locally but herein is ranked ninth.

Habitat Corridor Studies

Grizzly bear habitat or travel corridors have been poorly addressed in both research and management and are not considered adequately in the Grizzly Bear Recovery Plan (GBRP 1980). Travel corridors may not contain adequate habitat to sustain local bears, but the roles of corridors in connecting population units and habitats cannot be overly stressed. The loss of travel corridors leads to the isolation of populations into "islands," which greatly amplifies the research and management efforts needed and their costs. This study should rank high where critical corridors are being lost (Evaro Pass, the Coram to West Glacier Area, Marias Pass to East Glacier); however, we rank habitat corridor studies tenth.

Other Research

A wide spectrum of grizzly bear habitat research was initiated in the BGA in 1975, but much of this effort has been curtailed bureaucratically since 1980, so the research is still wanting today when it is so crucially needed. Additional and continuing studies worth mentioning are further cambium use studies; studies of the relationships between drought years, plant food production, bear nutritional levels, and bear-people conflicts; and habitat modeling development.

As habitat conditions change with human population growth, most habitat research outlined herein must be repeated periodically to revalidate the data bases. Grizzly bears are an expensive species to maintain; they will become incredibly expensive to maintain as land uses proliferate. The demands for land use will parallel human population growth, which currently is many millions per month on a world scale. The grizzly will not escape that threat. Long-term research independent of government pressures is crucially essential and must be reinstated to set and guide management direction and planning.

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Session IV—Habitat Conditions

Chaired by:

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Jay Gore, Assistant Field Supervisor, Ecological Services, U.S. Fish and Wildlife Service, Boise, ID

CLIMATE, CARRYING CAPACITY, AND THE YELLOWSTONE GRIZZLY BEAR

H. D. Picton, D. M. Mattson, B. M. Blanchard, and R. R. Knight

ABSTRACT: For a quarter century the Yellowstone grizzly bear population inspired public controversy. The major hypothesis has been that human-caused mortality is a primary influence upon this population. The effects of natural controlling factors have only been nominally explored. Habitat available to the population is characterized by sporadic and widely fluctuating food production primarily controlled by weather. The natural carrying capacity of the overall habitat fluctuates accordingly. During years of low carrying capacity, bears compensate by using a larger area and more of them are likely to die. The naturally low reproductive rate of the grizzly bear precludes quick population adjustment to fluctuating carrying capacity. Management strategies should therefore be geared to a worst-case situation. Indexes of food availability for each habitat type are computed and related to climatic conditions. The range of climatic conditions that can be expected is estimated from recent weather records. The worst-case climatic and food-producing situation is then described and can be prepared for.

INTRODUCTION

The Yellowstone grizzly bear population has inspired public controversy for over 25 years. Although over 30 years of research has produced more data on this grizzly population than any other, its precise status is still uncertain. All estimates of population trend have indicated a decline from 1970 to 1980, if not longer (Craighead and others 1974; Knight and others 1984; Knight and Eberhardt 1985).

The grizzly bear's reproductive rate is naturally low compared to many other mammal species. It's reproductive rate for the late 1970's and early 1980's (Knight and Eberhardt 1985) was lower than during the 1960's (Craighead and others 1974). A major concern has been that combined human-caused and natural mortalities will continue to exceed the birth rate to a point that could be catastrophic to the population.

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The natural environment or carrying capacity for grizzly bears in and around Yellowstone National Park appears to fluctuate widely from year to year (Knight and others 1984). Natural control factors that directly affect the population or indirectly affect it by promoting human-caused mortality have only been nominally explored (Picton 1978; Picton and Knight in press). Effective management is unlikely unless the interaction between the human and natural regimes is understood and appropriately weighted.

The mean climatic conditions indicate the shifts in the biometeorological normal range that influence the ecological carrying capacity of the habitat. Thus, the carrying capacity can be expected to change slowly with the trends in mean precipitation and temperature. Climate is one of the major components of environmental resistance that is greatest at the ecological carrying capacity. If an animal population is near the carrying capacity, changes in environmental resistance (climate) will force changes in the population level. Recent analyses have shown that curvilinear responses such as those expected to be seen near the ecological carrying capacity are present (Fagan 1984) in the litter size-climate index relation previously reported by Picton and Knight (in press).

Short-term changes in climatic conditions might influence populations at the ecological carrying capacity. These year-to-year changes will be superimposed upon the long-term level of the population as determined by the long-term biometeorological normal climate (that is, mean $\pm$ 1 SD). Thus climatic effects have two components: those due to the long-term biometeorological normal climate and those due to the short-term variations about the mean. The weather of the last 10 years has been extreme (Science 1985), with extreme precipitation values (both wet and dry) occurring in 5 of the 9 years in the 1974-82 period in the Yellowstone area (National Oceanographic and Atmospheric Administration 1974-1984).

The objectives of this paper are to use the existing data base on the grizzly bear and climatic records for the Yellowstone area to define the interactions between them, predict the extremes that can reasonably be expected, and suggest management objectives that will take natural factors into consideration.

Data on the grizzly bear population were taken from information gathered by the Interagency Grizzly Bear Study Team (IGBST) from 1973 through

1984 (Knight and IGBST 1975-1984). Climatic data were taken from Yellowstone National Park and U.S. Weather Bureau records. Field methods have been presented in IGBST annual reports (Knight and IGBST 1975-1984) and by Knight and others (1984).

METHODS

Climate Score Calculation

Climate score is an index calculated to approximate the impact of climate on food availability and thus on grizzly bears. The score was calculated on a seasonal and yearly basis, with the algorithm tailored to each season.

Precipitation, temperature, and their deviations from long-term seasonal averages of the Mammoth, Lake, and West Yellowstone weather stations were the variables entered in climate score calculations (table 1). Precipitation variables took the form of percent deviations from long-term averages; that is, seasonal precipitation values were scaled to long-term averages and multiplied by 100. Temperature variables also took the form of absolute percent deviations from long-term averages, but with the freezing point, or 32 ^{o}F (0 ^{o}C), as a base reference point. The 32 ^{o}F was subtracted from the calculation period seasonal temperatures and the long-term means. The resulting values were scaled to long-term averages and multiplied by 100.

Table 1.--Calculation of the seasonal climate score

Season	Percent long-term average precipitation	Percent long-term average degrees F above 32
Winter	WP_i	WT_i
Spring	SP_i	ST_i
Summer	SuP_i	SuT_i
Fall	FP_i	FT_i

SCS_i = spring climate score (year i).

$SuCS_i$ = summer climate score (year i).

FCS_i = fall climate score (year i).

$SuPS_i = (WP_i + SP_i + SuP_i)/3.$

$SCS_i = [(WP_i + SP_i)/2] + [(ST_i + WT_i)]/2.$

$SuCS_i = SuPS_i * [(ST_i + SuT_i)/2].$

$FCS_i = [SuPS_i/2) + (200 - FP_i)/4] + FT_i.$

Spring and winter climates were assumed to influence spring food sources by both spring (SP) and winter precipitation (WP) and temperature. Greater spring and winter precipitation, almost wholly as snow, and colder winter temperatures (WT) were considered to favorably affect spring food availability by causing greater death and debilitation among wintering ungulates. Warmer spring temperatures (ST) were also assumed to increase spring food resources by allowing earlier vegetation growth. Thus calculation of the spring climate score (SCS) took the form:

$$SCS_i = [(WP_i + SP_i)/2] + [(ST_i + WT_i)/2]$$

Summer food resources were assumed to be influenced by spring and summer temperatures and by winter, spring, and summer precipitation. Influences of climate were thought to be reflected primarily in availability and succulence of the grazing resource. Greater averaged winter, spring, and summer (SuP) precipitation and higher spring and summer (SuT) temperatures were assumed to correspond to greater grazing resources. Thus, summer climate score (SuCS) calculation took the form:

$$SuCS_i = [(WP_i+SP_i+SuP_i)/3] * [(ST_i+SuT_i)/2]$$

Availability of fall food sources was assumed to be influenced by growing season moisture conditions as well as fall precipitation and temperatures. Higher fall temperatures (FT) and lower fall precipitation (FP) were assumed to allow access to food sources later into the fall. More favorable growing season moisture conditions, reflected in greater averaged winter, spring, and summer precipitation, were assumed to produce persistent higher quality grazing resources into the fall. Thus, the fall climate score calculation (FCS) took the form:

$$FCS_i = [(WP_i+SP_i+SuP_i)/6]+[(200-FP_i)/4]+FT_i$$

Habitat Quality Index

Calculation of the habitat quality index for Yellowstone Park was based in part on the proportionate cover of habitat types and habitat type mosaics in Yellowstone Park (Despain 1977). Derived coefficients were specific to each season of each year and to each type or mosaic cover. The habitat type coefficients were based on community site and scat analysis data collected during the season and year for which habitat quality was being calculated.

Methodology for coefficient derivation followed Mattson and others (1985). Multiplication of coefficients and proportionate area for each type or mosaic followed by summation of these products over all types yielded an index of habitat quality for the Park for a specific season and year.

RESULTS

Climate

We compared climatic years 1977 and 1980. Greater precipitation in all seasons was the major climatic factor by which 1980 differed from 1977 (table 2). All seasons except winter were wetter than normal during 1980; the composite precipitation total for 6 weather stations was 100 percent of normal. On the other hand, all seasons of 1977 were droughty; the composite total (stations) was 96 percent of normal. Each year had been preceded by a drier year. Temperatures differed less markedly between the years. Spring and winter of 1977 were somewhat colder and fall was slightly warmer than corresponding seasons of 1980.

Greater precipitation during 1980 influenced food availability primarily by producing more during the summer. It also affected the ungulate food source (Houston 1982) by producing more carrion and weakened ungulates during the spring.

Table 2.--Comparisons of climate, habitat, and grizzly bear observations for 1977 and 1980

	1977			
	Spring	Summer	Fall	Annual
Habitat quality index	0.865	0.677	0.714	0.719
Climate score	0.718	0.605	0.967	0.763
Percent of all bears aerially observed outside of Yellowstone National Park on standard flight routes[1]	7	38	0	21
Seasonal rate of movement index	0.827	1.000	1.000	1.000
Mean home range size (km^2)				754
Human-caused known and probable mortality (number of bears)				13
Mean annual rate of weight gain (spring to fall) in kg/day				0.36

[1]These do not represent a systematic aerial survey of all areas outside of Yellowstone Park, but only bears incidentally seen on the consistent radio survey routes.

Slightly warmer 1980 spring temperatures probably also increased the availability of spring grazing opportunities in favored microsites. Conversely, greater fall precipitation coming as snow, during 1980, decreased foraging opportunities and perhaps encouraged earlier denning.

The climate score (table 2) reflects expected climatic influences on food availability during 1977 and 1980. Spring and summer climate scores were substantially higher during 1980 compared to 1977 but differed only marginally during fall of the 2 years.

Food Habits

Food habits during 1977 and 1980 reflected the climatic conditions as well as the less closely predicted availability of whitebark pine (Pinus albicaulis) nuts (fig. 1 and 2).

Although the proportionate volumes of ungulates ingested during the springs of 1977 and 1980 were nearly equal (Knight and IGBST 1977, 1980), total use of winter-killed and weakened animals (based on the proportion of all observed bears using carcasses during comparable survey flights) was less in 1977 than 1980. On a per-unit scat diet-volume basis, ingestion of ungulates was much the same during spring of 1977 and 1980, but was probably significantly less per unit time during 1977.

Proportionate diet item consumption differed markedly between the summers of 1977 and 1980 (fig. 1 and 2). Food is usually readily available during summer so that per-unit-time ingestion rates probably did not differ significantly between the 2 years. Consequently, proportionate diet item volumes give a clear picture of the substantial dietary differences between 1977 and 1980.

The summer diet of 1977 was distinguished by an unusually large proportion of ants and biscuitroot (Lomatium cous) and complementarily sparse amounts of grazed vegetal foods (fig. 1 and 2). These characteristics matched the effects of drought on the availability of summer foods. The foliferous vegetal foods availability and use were apparently very sensitive to the concurrent soil moisture status, whereas ants and root foods were buffered from the short-term drought effects.

The summer diet in 1980 contrasted to that of 1977. The 1980 grizzly bear diet was dominated by the foliferous vegetal foods and included few ants and roots. This agrees with ample soil moisture conditions and average to above-average growing season temperatures.

Fall diet also differed markedly between 1977 and 1980. The fall of 1980 was distinguished by the ingestion of large proportions of whitebark pine nuts, whereas the fall of 1977 was notable for the use of large volumes of yampa (Perideridia gairdneri) roots and virtually no pine nuts.

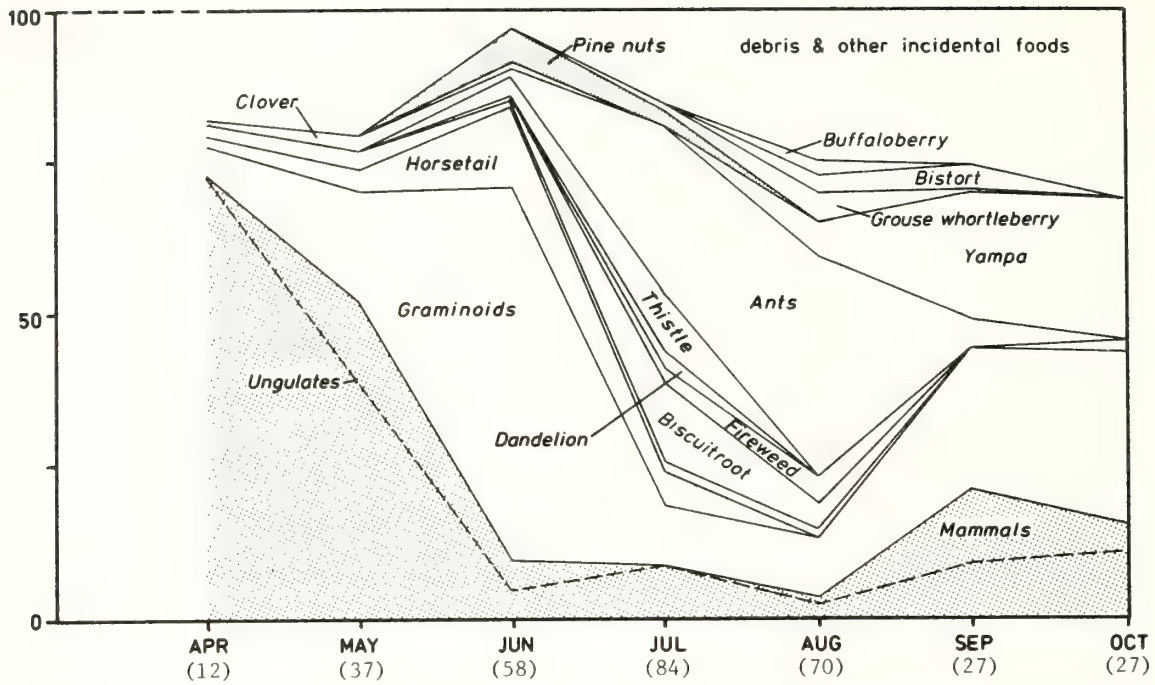


Figure 1.--Volumetric analysis of grizzly bear scats, by month, for 1977. Sample sizes are given in parentheses by month.

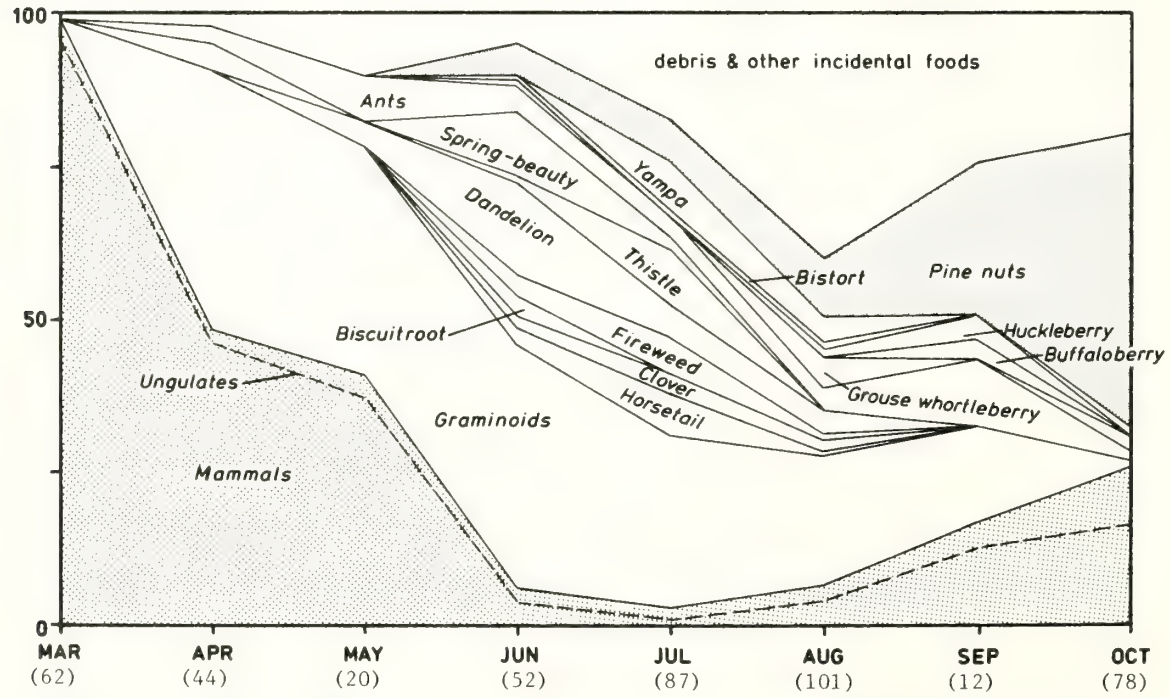


Figure 2.--Volumetric analysis of grizzly bear scats, by month, for 1980. Sample sizes are given in parentheses by month.

Elevational distribution of fall grizzly bear radio relocations reflected the disparity in fall food habits between 1977 and 1980. Average relocation elevation was considerably lower during 1977 (average = 2 361 m) compared to 1980 (average = 2 579 m) (Knight and IGBST 1977, 1980). This apparently reflected the consumption of yampa in mesic habitats at moderate elevations and the consumption of whitebark pine nuts in higher elevation forested habitats.

The dietary patterns reported above are further confirmed by an extensive series of correlations with R^2 values of 0.76 (ants), and 0.80 (graminoids) derived from the 1977 to 1982 climate score and scat analysis data series.

Habitat Quality

The seasonal and annual habitat indexes for Yellowstone National Park, which are estimators of the carrying capacity, reflected food availability, and indirectly, climate for the study years (table 2). The habitat quality index rates 1980 as a much higher quality year than 1977. Of the 7-year (1977-83) study period, only 1981 rated as a poorer year than 1977, whereas no other year exceeded 1980 in quality (table 3).

The seasonal deviation in the habitat index was greatest between the summers of 1977 and 1980. The 1977 summer food habits were notable, during the 1977-83 study period, for the paucity of grazed vegetal foods and the large volume of ants. Conversely, the 1980 summer habitat values were slightly enhanced over those normally associated with ample grazing resources by a large proportion of high-energy-value fruit (huckleberry [Vaccinium globulare] and grouse whortleberry [V. scoparium]). Differences between the habitat indexes for the two summers were consequently large (0.677 compared to 1). Summer climate scores closely matched the summer habitat indexes, suggesting that annual differences in habitat quality probably reflected winter, spring, and summer climates.

Table 3.--A summary of the annual climate scores and habitat quality indexes for the 1977 to 1982 period

Index	Year					
	1977	1978	1979	1980	1981	1982
Climate score	0.740	0.903	0.887	0.969	0.838	1.000
Habitat quality index	0.752	0.802	0.943	1.000	0.596	0.846
Mean home range size (km^2)	754	642	766	338	413	366

Seasonal differences in habitat quality for 1977 and 1980 were least during spring. Although the 1977 index value was less, in large part because of less unit-area consumption of ungulates (Mattson and others this volume), the disparity was not great. Feeding site and climate data suggest that the fewer available ungulates during the spring of 1977 were in part compensated for by a greater area of available grazing resource. The differences between the spring climate score and the spring habitat index probably reflected the greater sensitivity of the climate score to the availability and use of the spring grazing resource.

Differences in the fall habitat index for the two study years primarily reflected the availability and use of high-value pine nuts during 1980 and their virtual absence from the landscape and diet in 1977. The habitat index score during 1977 was buoyed, however, by the near-normal consumption of the equally high-value ungulates.

The large discrepancy between fall values of the climate and habitat indexes also primarily reflected use of pine nuts during 1980. Availability of pine nuts is largely dissociated from the contemporaneous climate, since pine nuts need 2 years to mature. Thus the habitat index values derived from the use of pine nuts are largely unpredicted by the fall climate score as presently calculated.

Movements

Three variables associated with grizzly bear movements were measured on a seasonal or annual basis: (1) the percentage of all bears located outside of Yellowstone Park that were observed from the air during consistent radio survey flights (these were not attempts to survey all areas outside the park); (2) an index of the seasonal rate of movement; and (3) the average annual home range size for grizzlies radio-tracked during the entire study year. These variables indicated that grizzly movements during 1977 and 1980 were very sensitive to climatic and habitat conditions (tables 2 and 3).

The percentage of bears located outside Yellowstone Park that were observed from the air showed annual and seasonal differences between 1977 and 1980. The best year for habitat quality during the 1977 to 1983 study period was 1980. Significantly, during that year, no grizzlies were observed from the air outside of Yellowstone Park. In contrast, 38 percent of all grizzlies observed during the summer of 1977 were seen outside the park. Averaged over the year, 21 percent of all grizzlies seen in 1977 were located outside the park. This movement relationship is further supported by the 6-year (1977-82) correlation, which has an R^2 value of 0.53 ($P < 0.1$).

Seasonal and annual rates of movement were also decidedly sensitive to climate and habitat conditions. During summer and fall, movements were approximately one-half as much during 1980 as they were during 1977. Wetter climatic conditions and greater habitat value apparently produced less mobility. Spring movements showed an opposite response to climate and habitat. Greater mobility was associated with greater habitat quality (that is, greater numbers of available ungulates).

Smaller annual home range sizes during 1980 compared to 1977 reflected the habitat quality and climate. The smaller ranges were apparently a result of wetter climatic conditions and greater habitat quality and climate. The smaller ranges were apparently a result of wetter climatic conditions and greater habitat quality. The 1977-82 data base gave a correlation R^2 value of 0.66 ($P < 0.05$) to support the belief that this is a consistent relationship.

Mortality

Human-caused mortalities in recent years have occurred primarily when grizzlies attempted to acquire human foods within the human domain. The numbers of such mortalities were quite sensitive to climatic and habitat conditions (table 2). During the austere year of 1977 over twice as many grizzlies died of human-related causes as during 1980. Apparently grizzly mortality was much more likely during drier years such as 1977, when fewer ungulates and few pine nuts were available, than during a year when all high-value foods were seasonally abundant, as in 1980. A correlation analysis for the 1977-82 period (for summer $R^2=0.98$ [$P < 0.01$]; for fall $R^2=0.91$ [$P < 0.01$]) suggests that this was a general relationship.

Weight Gain

Seasonal weight gain was the final response variable examined in this analysis. Again, the pattern was consistent. The average daily weight gain under austere 1977 conditions was less than one-half the 1980 rate (table 2; Knight and IBGST 1977, 1980).

Other

Other population parameters appear to respond to annual variations in climate and habitat quality. Cub-sow ratios and age-class survivorship are examples of such parameters.

For example, from 1977 to 1982, the cub-sow ratio was correlated with habitat quality averaged for the contemporaneous spring and summer with an R^2 of 0.82 ($P < 0.05$).

It was further found that the survivorship of cohorts through their first 5 independent years was inversely correlated with the habitat quality they had experienced as cubs ($R^2=0.83$, $P < 0.05$).

DISCUSSION

We examined the impact of climate upon various biological attributes during 2 years with contrasting climates. The results seen during these 2 years were also compared to a 7-year data set (1977-83) when possible.

The climate score used in this paper follows the degree day approach common in agronomy. The habitat quality index is an attempt to represent the bears' view of the habitat. The analytical procedures emphasized the annual variations from mean conditions.

A response syndrome was clearly present. Low availability of pine nuts and years with poor growing conditions increased the amount of ants and roots in the summer and fall diet as compared to grazed vegetal foods and pine nuts. This in turn resulted in a lower weight gain, an increase in foraging movements, and a greater human-induced mortality rate.

The data are consistent with the net energy gain movement-triggering hypothesis of Baker (1978). That is, movement is stimulated, resulting in larger home ranges, when the net energy gain drops below a threshold level. The weight gain relationships with diet appear to be consistent with mammalian nutrition studied that suggest that late summer-fall hyperphagia might be triggered by an increase in lipids and certain simple sugars in the diet, which in turn stimulate fat deposition (Glick 1984). This interpretation is consistent with the food analyses done by Mealey (1975) and indicates that diet quality as well as quantity is important. The shift away from the grazing resource during dry years probably is due to the early loss of succulents and related nutrients during these dry years. The shift is more likely due to loss of quality rather than quantity and thus competition with ungulates is probably not significant.

Harting (1985) found that use of ungulates and human garbage can make otherwise unattractive habitats usable to grizzlies. The bears in his study that followed this feeding strategy tended to forage more widely than animals relying upon the vegetal resource. Increased employment of a comparable feeding strategy probably characterizes the response of Yellowstone grizzlies to droughty years. The high mortality rate of the bears during dry years suggests that the bears have or develop a preference for human-associated foods, are forced into areas with greater human presence and potential conflict, because the habitat within one home range diameter of the park is saturated, or simply randomly increase movements beyond the park boundaries.

The annual rate of increase of the Yellowstone grizzly population (Knight and Eberhardt 1985) is below the level expected for a mammal of its size from the general mammalian reproductive allometric equation. Thus, the population is at carrying capacity and is undergoing K selection. This is further confirmed by the litter size-climate

relationships previously reported (Picton 1978; Picton and Knight in press). This paper examines some of the mechanisms by which a population responds to climatic variation. Because of the small number of females (Knight and Eberhardt 1984), it is questionable whether the present population can obtain full benefit of positive climatic variations. It may therefore be desirable to formulate and discuss management options to help the population benefit more from the climatic variations than is possible with its current structure and long turnover time.

The Yellowstone grizzly bear reserve should be maintained with an eye to the future. Yellowstone National Park lies in the convergence zone between the subtropical and the circumpolar jet streams (Stockton 1973); thus the climate can vary substantially from year to year, depending upon the relative shifts of the two jet streams. This study includes years having bad climatic conditions as well as some good ones; however, long periods at the extremes are not included. If the Yellowstone grizzly reserve is to be managed for the indefinite future we must consider the probable atmospheric CO_2-induced climate change that may be upon us within the next 10 years (Kellogg and Schware 1981). Grizzly bear-climate studies suggest that this population may be significantly affected by such a change, which may involve an annual mean temperature rise at the latitude of Yellowstone area equal to or exceeding the most extreme years of the 20th century and approaching the estimate for the Altithermal period (about 5,500 years before present) (Manabe and Wetherald 1980; Houston 1982). Research and management policies should focus not only on the individual poor year contingency, but also on foreseeable climate change options so that the Yellowstone grizzly reserve remains a reserve for the indefinite future.

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ANALYSIS OF GRIZZLY BEAR HABITAT IN THE BOB MARSHALL WILDERNESS, MONTANA

Richard D. Mace

ABSTRACT: The Grizzly Bear Recovery Plan of 1982 was adopted to provide a sequence of management actions necessary for the conservation and recovery of grizzly bears in selected portions of the contiguous 48 States. The Plan identified six ecosystems, the largest of which is the Northern Continental Divide Ecosystem. Although the Bob Marshall Wilderness constitutes approximately 17 percent of this ecosystem, no habitat descriptions for the Wilderness were available. Recent ecological studies have shown that grizzly bear habitat use patterns can be explained in terms of the distribution of major food items. Therefore, the primary objective of this study was to establish detailed vegetation descriptions of habitat components occurring in the temperate, subalpine, and alpine zones of the study area. Eight habitat components were identified and sampled. Within these components, 28 vegetation types were sampled by stratified random sampling. Vegetation information was also obtained for three forest habitat types. The foraging quality of these 28 vegetation types was evaluated for two foraging seasons (herbaceous season, fruit season). Each vegetation type was evaluated on the basis of succulent foods, modified stems (roots, corms, bulbs), and fruit. During the herbaceous season, the tallgrass/Senecio triangularis vegetation type (subalpine meadow component) ranked first in succulent foods. Several vegetation types of the avalanche chute complex and flood plain complex also ranked high in succulent foods for this season. Vegetation types of the flood plain complex, slabrock, and alpine complex components ranked high for modified stems. The Abies lasiocarpa/Xerophyllum tenax-Vaccinium globulare forest habitat type ranked highest of all types for those fruits favored by grizzly bears. Abbreviated descriptions of each component and vegetation type are given. This information will assist wilderness management programs and will aid in the comparisons of habitat quality among areas.

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INTRODUCTION

The land base occupied by the grizzly bear in the contiguous 48 States has been divided into six major ecosystems, the largest of which, the Northern Continental Divide, is located in western Montana. Although the Bob Marshall Wilderness constitutes approximately 17 percent (424 500 ha) of this ecosystem, no habitat descriptions for the Wilderness were available. As stated in the Grizzly Bear Recovery Plan (U.S. Department of the Interior 1982): "The value of wilderness areas to grizzly bears in this ecosystem is undocumented. They may contain habitat values superior, inferior, or equal to those in peripheral areas."

The objectives of this study were to establish detailed vegetation descriptions of habitat components occurring in the temperate, subalpine, and alpine zones and to develop a seasonal ranking of grizzly bear habitat based on food composition and temporal availability.

STUDY AREA DESCRIPTION

The study area was located in the southern portion of the Bob Marshall Wilderness. Major drainages within the approximately 40 400-ha study area included Gordon, Babcock, and Youngs Creeks and a portion of the South Fork of the Flathead River flood plain (fig. 1).

The area is rugged mountain terrain located within the Rocky Mountain Cordillera. Parent material is of sedimentary origin. The western study area boundary, the Swan Range, was uplifted and tilted between 70 and 60 million years ago (Deiss 1958). Mountain glaciers have formed the U-shaped valleys, cirques, hanging valleys, horns, and aretes in evidence today. Elevation varies from 1 423 m along the South Fork of the Flathead River, to 2 761 m on Ptarmigan Peak along the Swan Crest.

Maritime air masses moving from the Pacific Ocean strongly influence the study area (Daubenmire 1969); however, precipitation in the southern portion of the Bob Marshall is moderated by the Mission Mountains to the west.

Rugged mountain topography and complex local climates create an array of vegetation. Dry open slopes occur in rain shadows, and cool, moist

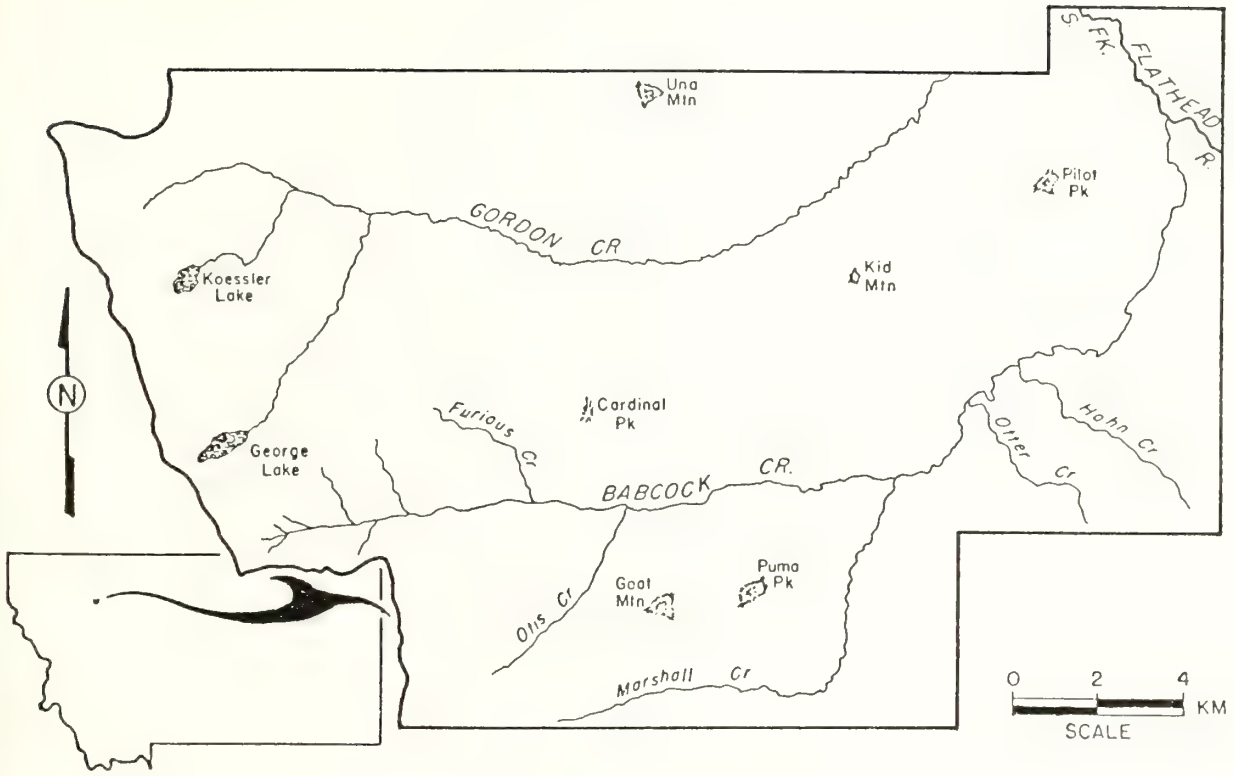


Figure 1.--The study area.

drainages are located in areas of relatively high precipitation and cloud cover (Arno 1979). The study area contains the Douglas-fir (Pseudotsuga menziesii), spruce (Picea spp.), and subalpine fir (Abies lasiocarpa) habitat type (h.t.) series of Pfister and others (1977). Plant taxa have adapted to natural fire, and seral vegetation forms complex mosaics throughout the area. The history and influence of fire in the Northern Rocky Mountains are given by Steele (1960), Habeck and Mutch (1973), and Arno (1980).

METHODS

Field Procedures

Field work was conducted from June through September of 1982 and 1983. Existing habitat component categories served as a foundation for vegetation sampling. Component definitions developed for the lower South Fork of the Flathead River (Zager and others 1980), the Mission Mountains (Servheen 1981), and the Rocky Mountain East Front (Aune and Stivers 1982) were field-checked to determine feasibility of use.

A 3-week initial reconnaissance was conducted to determine the general spatial arrangement of major vegetation types within each designated habitat component. Sample plots were placed within these vegetation types by stratified random sampling. Open-timbered and timbered vegetation (30 percent to 60 percent and >60 percent canopy cover) were sampled using 375-m^2 circular plots. Small vegetation types without conifer overstories were sampled using circular plots of 5 m^2. The number of plots taken in each vegetation type was determined in the field by construction of a species-area curve (Mueller-Dombois and Ellenberg 1974). Sampling of a specific vegetation type was terminated when no new taxa were encountered after three consecutive plots were taken. Complete taxa lists were compiled, although grasses and sedges were combined. Cover values for each plant species and nonvascular material were visually estimated using the modified Daubenmire cover classes of Pfister and others (1977): 0=absent; T=trace-1 percent; A=1-5 percent; B=5-25 percent;

C=25-50 percent; D=50-75 percent; E=75-95 percent; and F=95-100 percent.

Botanical nomenclature followed Hitchcock and Cronquist (1973). Timbered sites were keyed to the appropriate forest habitat type of Pfister and others (1977). Tree, shrub, and herbaceous cover per stratum were recorded in each plot. Height categories employed were: A=0-0.9 m; B=0.9-2.0 m; C=2.0-9.0 m; and D= >9.0 m.

Analytical Procedures

Pressed plant specimens were verified by Peter Stickney (Intermountain Research Station, Missoula, MT). Vegetation data were then assembled into association tables to scrutinize relationships among plots (Mueller-Dombois and Ellenberg 1974). Plot data were then entered into a DEC-20 computer.

Average percent cover was derived by summing the cover class midpoints for a species and then dividing the summation by the total number of plots in the vegetation type. Relative cover and percent occurrence values were also determined for each taxa.

A list of food items in the study area was collated using recent literature on grizzly bear food habits from the Northern Rocky Mountains of the United States and southern British Columbia, Canada (Russell and others 1979; Aune and Stivers 1982; Craighead and others 1982; Sumner and Craighead 1973; Mace and Jonkel in press). Food items were placed into one of three major food categories: succulent vegetation; modified stems (roots, bulbs, or corms); or fruit. Each food item was given a seasonal preference rank. A rank of 3 represented an often-selected food; a rank of 2 was given to food plants of moderate use; and a rank of 1 meant low use. For each sample plot within a vegetation type, preference ranks were multiplied by the midpoint of the cover class of each food to develop a "food item importance value" (FIIV). "Vegetation type importance values" were obtained by simply summing the FIIV's in each plot and then averaging over all plots in the vegetation type.

Two seasonal categories were used: a "herbaceous foraging season" (den emergence to July 31), and a "fruit foraging season" (August 1 to den entry). Test of statistical differences among "vegetation type importance values" for each season and each food category were accomplished using nonparametric Mann-Whitney (M-W) procedures (Nie and others 1975).

RESULTS

Eight grizzly bear habitat components were designated for the study area. Within these components, 28 vegetation types were identified and sampled as follows:

1. Flood Plain Complex Habitat Component
    a. Salix spp. flat VT
    b. Sandbar and gravel bar VT'S
    c. Carex spp. VT
    d. Mesic herbaceous meadow VT
    e. Riparian Picea VT
    f. Populus trichocarpa VT
    g. Terrestrial Picea VT
    h. Xeric graminoid meadow VT
2. Avalanche Chute Complex Habitat Component
    a. Streamside VT
    b. Alnus shrubfield VT
    c. Xerophyllum tenax VT
    d. Xeric, warm-aspect VT
    e. Mesic herbaceous fan VT
    f. Xeric herbaceous fan VT
3. Timber Creek Bottom Habitat Component
    a. Closed timber VT
    b. Glade (opening) VT
4. Mountain Sidehill Park Habitat Component
    a. Mixed graminoid VT
    b. Xeric bunchgrass VT
5. Burn Shrubfield Habitat Component
    a. Temperate zone burn shrubfield VT
    b. Subalpine zone burn shrubfield VT
6. Subalpine Meadow Habitat Component
    a. Shortgrass/Phyllodoce empetriformis VT
    b. Hydromesic herbaceous VT
    c. Tallgrass/Senecio triangularis VT
7. Slabrock Habitat Component
8. Alpine Complex Habitat Component
    a. Fellfield VT
    b. Mesic alpine meadow VT
    c. Vegetated rock/talus VT

Given below are brief descriptions of each habitat component and associated vegetation types. Complete vegetative and physiographic descriptions are given by Mace (1984).

Grizzly Bear Habitat Components

Flood plain complex habitat component.--The flood plains of the study area were divided into two zones, riparian and terrestrial (U.S. Department of Agriculture 1978; Pfister and Batchelor 1984). The riparian zone was adjacent to the river channel and susceptible to annual or periodic flooding. The terrestrial zone was that area of undulating and terraced valley floor not subject

to flood waters. Nonforested types of the riparian zone included willow (Salix spp.) flats, mesic herbaceous meadows, sand bars, and gravel bars. Mature stands of the spruce/queencup beadlily (Clintonia uniflora) and spruce/fragrant bedstraw (Galium triflorum) h.t. series were present on unburned islands and oxbows. Blocks of highly stocked lodgepole pine (Pinus contorta) and Douglas-fir interspersed with xeric graminoid/big sagebrush (Artemisia tridentata) meadows occupied well-drained terraces of the terrestrial zone. The flood plain complex was formed by valley glaciers and exhibited a U-shaped topography. The elevation of these low-gradient river or creek bottom lands varied from 1 415 to 1 576 m.

Avalanche chute habitat component.--Avalanche chutes were a combination of vegetation types subjected to annual or periodic cascading snow. They typically formed in the linear and concave irregularities of steep mountain slopes; however, chutes also existed as extensive open and undulating parks beneath steep mountain headwalls and palisades. Vegetation types of this component included supple-stemmed alder (Alnus spp.) shrubfields on cool and moist aspects; mesic streamside vegetation; xeric-aspect vegetation; and beargrass (Xerophyllum tenax) bowls. Seven avalanche chutes were sampled, each of which represented a major cardinal direction.

Timbered creek bottom habitat component.--The secondary drainages of the study area exhibited an overstory canopy cover greater than 60 percent. Habitat types in the sample areas were either subalpine fir/bluegrass reedgrass (Calamagrostis canadensis) or subalpine fir/fragrant bedstraw. Small openings (the glade VT) in the canopy along stream channels or in "blow-down" areas were common. The elevation of this habitat component varied from 1 439 to 1 740 m.

Burn shrubfield habitat component.--Seven burn shrubfields were sampled. These were divided into temperate zone burn VT (<2 121 m), and a subalpine zone burn VT (>2 121 m). The most recent period of burnings for temperate zone shrubfield was 1926. Paired-plot data suggest that these sites were once an open-timbered Douglas-fir forest. Herbaceous dominants included arrowleaf balsamroot (Balsamorhiza sagittata), western hedysarum (Hedysarum occidentalis), and fireweed (Epilobium angustifolium). Evergreen ceanothus (Ceanothus velutinus) and serviceberry (Amelanchier alnifolia) were dominant shrubs.

The subalpine zone burns sampled burned either in 1929 or 1934 and occurred within the subalpine fir/beargrass-grouse whortleberry (Vaccinium scoparium) h.t. Beargrass was the dominant taxa, having a relative cover value of 52 percent. Arrowleaf balsamroot, entire-leaved aster (Aster integrifolius), and fleabane (Erigeron spp.) dominated particularly xeric and shallow-soiled microsites. Globe huckleberry (Vaccinium globulare) exhibited a 3 percent cover.

Forest habitat types.--Three forest h.t.'s were sampled for cover and occurrence of shrub taxa. The subalpine fir/beargrass-globe huckleberry h.t. occurred on southern exposures in the temperate and lower subalpine zones. This type was sampled on benches above timbered creek bottoms and in open-timbered to timbered stringers in avalanche chutes. The subalpine fir/woodrush (Luzula hitchcockii)-grouse whortleberry h.t. occupied sites above 2 121 m on all exposures. The subalpine fir/fool's huckleberry (Menziesia ferruginea) h.t. occurred on northern exposures.

Mountain sidehill park habitat component.--Openings in the forest canopy at midelevations occurred on mountain slopes. Although present on all aspects, such sidehill parks typically occupied residual soils on southern exposures. These parks were often dominated by grasses and maintained by periodic light ground fires (Johnson 1982). Two vegetation types of this component were identified. The first, a mixed graminoid VT, was dominated by bluebunch wheatgrass (Agropyron spicatum), Kentucky wheatgrass (Poa pratensis), common timothy (Phleum pratense), western needlegrass (Stipa occidentalis), and fringed bromegrass (Bromus ciliatus). Serviceberry and oregongrape (Berberis repens) were considered dominant shrubs. Nonvascular ground cover was 19 percent. Numerous parks supported a dry bunchgrass vegetation dominated by Idaho fescue (Festuca idahoensis). Such areas, termed a xeric bunchgrass VT, generally exhibited a low cover of plant taxa and high cover of bare ground and rock (69 percent cover).

Slabrock habitat component.--The uplifting and tilting of parent material during the mountain-building eras resulted in exposed and often terraced slabs of glacially scoured rock. Subsequent erosion allowed soil and vegetation development between these slabs of rock. This slabrock component was located at the head of cirque basins. Dominant herbs were woodrush pussy-toes (Antennaria luzuloides), beargrass, and subalpine buttercup (Ranunculus eschscholtzii). Sandberg's biscuit-root (Lomatium sandbergii) was restricted to the most xeric habitats, either in slabrock crevices or on gravelly surfaces abutting the rock slabs. The cover values of rock slabs, total ground vegetation, and conifers were 36, 48, and 16 percent, respectively.

Subalpine meadow habitat component.--Open meadows of variable species composition were present beneath the headwalls of cirque basins. Meadows were also present along the terminus of snow fields and near perennial and ephemeral streams. Elevation of the meadows sampled varied from 2 061 to 2 291 m. Three distinct subalpine meadow VT's were sampled. A dense turflike pattern of vegetation was distinctive in the shortgrass/red mountain-heather (Phyllodoce empetriformis) VT. Senecio spp. (S. pseudaureus or S. resedifolius), elkslip marigold (Caltha leptosepala), and fleabane (Erigeron spp.) were dominant herbs. Surface and subsurface water

runoff saturated soils in which vegetation was growing in the hydromesic herbaceous VT. Dominant taxa in these hydric microsites included brook saxifrage (Saxifraga arguta), elkslip marigold, glaucous zigadenus (Zigadenus elegans), and alpine laurel (Kalmia polifolia). The third subalpine meadow type (tallgrass/Senecio triangularis VT) occurred within the subalpine fir/bluejoint reedgrass and the subalpine fir/woodrush h.t.'s. These partially shaded meadows exhibited a luxuriant growth of grasses and sedges. The dominant herb and grass were arrowleaf groundsel (Senecio triangularis) and bluejoint reedgrass.

Alpine complex habitat component.--Sites exhibiting characteristic alpine flora were generally found above an elevation of 2 310 m. Nontimbered alpine vegetation consisted of xeric fellfields and mesic forb/sedge meadows. Exposed bedrock, boulder fields, and sparsely vegetated cobblefields comprised large areas of this component. The fellfield VT was sampled on the most severely exposed and wind-swept surfaces of mountain peaks. Cushion plants were conspicuous in fellfields and included pale alpine forget-me-not (Eritichium nanum), Rocky Mountain douglasia (Douglasia montana), alpine smelowskia (Smelowskia calycina), and few-seeded draba (Draba oligosperma). White dryas (Dryas octopetala) was the subshrub of greatest coverage. The mesic alpine meadow VT was located directly below sites of high snow accumulation. The two dominant herbs in this type were subalpine buttercup and creeping sibbaldia (Sibbaldia procumbens). Unstable rock and talus slopes typified the vegetated rock/talus VT. Arnica (Arnica spp.), leafy-bract aster (Aster foliaceus), and yellow buckwheat (Eriogonum flavum) were dominant herbs.

Seasonal Ranking of Vegetation Types

The 28 vegetation types and three forest habitat types were evaluated for two foraging seasons: a herbaceous season (den emergence to July 31), and a fruit season (August 1 to den entry). Three assumptions were made in the seasonal analyses of habitat:

1. Four major categories of foods would be selected by grizzly bears during those seasons when the foods were phenologically available. The four categories were:

   a. Succulent vegetation (both seasons)
   b. Underground roots, corms, and bulbs (modified stems) dug by grizzly bears during both seasons
   c. Fruit (fruit foraging season)
   d. Whitebark pine nuts (both seasons)

2. A grizzly bear would forage in a small vegetation type if preferred foods (as dictated by food category) were present, even if the corresponding habitat component was of low seasonal value. Grizzly bears would select types with the greatest cover and occurrence of these foods.

3. Grizzly bears would find adequate cover and occurrence of grasses and sedges in all vegetation types. Elimination of these food items from seasonal rankings would provide a more realistic indication of the foraging value of the type.

Seasonal evaluations of vegetation types were based on the percent cover and seasonal preference ranks of specific food items of each food category. Food items used in these analyses (table 1) were collated from pertinent food habits literature.

Habitat components and their associated vegetation types were considered to be available to grizzly bears during all snow-free months. Table 2 shows the relationships among component availability, food categories, and foraging season. All habitat components except the slabrock, subalpine meadow, and alpine complex components were available throughout the grizzly bear's active season.

Vegetation Type Comparison for the Herbaceous Foraging Season (Den Emergence-July 31)

Table 3 shows vegetation type rankings for succulent plants and modified stems. The tallgrass/Senecio triangularis VT of the subalpine meadow component ranked highest of all types for succulent food items, even though not available until July. The importance value of this type was significantly greater than the closest ranking Alnus VT of the avalanche chute component (M-W $p=0.04$). The Alnus VT and the riparian Picea VT (flood plain complex habitat component) ranked second and third respectively. These two types were available in May. The remainder of the top 10 ranking vegetation types were present in either avalanche chutes, creek bottoms, or flood plain complexes.

Table 4 gives the cover and occurrence of several "key" succulent foods per vegetation type. Gramineae/Cyperaceae was present in all types and showed the highest cover values of all foods. Cow parsnip (Heracleum lanatum) occurred in moist and cool vegetation types. The streamside VT and small openings in the Alnus VT had higher cover values of this food than other avalanche chute types. The mesic herbaceous fan VT of north-facing and west-facing chutes also showed high cover values of this food. Willow flats and mesic herbaceous meadows showed higher cover values of cow parsnip than other flood plain complex types.

Horsetail (Equisetum spp.) had the greatest observed cover in the glade VT of timbered creek bottoms. In the flood plain component, this food was most abundant in the riparian Picea VT and the Salix flat VT. Horsetail was noticeably absent in all avalanche chute types, suggesting the importance of a moist, cool, and shaded microenvironment as a growth medium.

The sand bar VT (flood plain complex) ranked highest of all types for roots, corms, and

Table 1.--Grizzly bear food items and preference ranks

Food item	Vegetation	Modified stems	Fruit
FORBS:			
Achillea millefolium	1		
Allium cernuum		2	
Allium schoenprasum		2	
Allium spp.		2	
Angelica arguta	3		
Aster conspicuus	1		
Aster foliaceus	1		
Aster occidentalis	1		
Aster spp.	1		
Astragalus alpinus		2	
Astragalus bourgovii		2	
Astragalus robbinsii		2	
Astragalus spp.		2	
Castilleja spp.	1		
Cirsium spp.	2		
Claytonia lanceolata		3	
Equisetum arvense	3		
Equisetum spp.	3		
Erythronium grandiflorum		3	
Fragaria virginiana	3		
Hedysarum occidentale		1	
Heracleum lanatum	3		
Ligusticum canbyi	2		
Ligusticum spp.	2		
Lomatium dissectum		1	
Lomatium cous		3	
Lomatium macrophyllum		3	
Lomatium sandbergii		3	
Lomatium spp.		3	
Osmorhiza chilensis	3		
Osmorhiza purpurea	3		
Osmorhiza occidentalis	3		
Osmorhiza spp.	3		
Oxytropis campestris		3	
Polygonum bistortoides		2	
Senecio triangularis	2		
Trifolium spp.	3		
Taraxacum spp.	3		
Valeriana sitchensis	2		
Valeriana occidentalis	2		
Veratrum viride	2		
SHRUBS:			
Amelanchier alnifolia			3
Arctostaphylos uva-ursi			2
Cornus stolonifera			2
Prunus virginiana			2
Rhamnus alnifolia			2
Ribes lacustre			1
Ribes viscosissimum			1
Ribes inerme			1
Ribes hudsonianum			1
Ribes spp.			1
Rosa acicularis			1
Rosa woodsii			1
Rosa spp.			1
Rubus idaeus			1
Rubus spp.			1
Shepherdia canadensis			3
Sorbus scopulina			3
Vaccinium scoparium			2
Vaccinium caespitosum			2
Vaccinium globulare			3

bulbs (table 3). Before July, the Xerophyllum tenax VT (avalanche chute complex) and the temperate zone burn VT also ranked relatively high. Beginning in July, the slabrock component and the mesic alpine meadow VT ranked 2 and 3 respectively. There was no significant difference between the sand bar VT and the slabrock component (M-W p=0.30).

A summary of those food items whose underground parts would be dug by grizzly bears is presented in table 5. During the early portion of the herbaceous foraging season, wild onion (Allium spp.) and milk vetch (Astragalus spp.) were the most widely distributed foods. Before July, glacier lily (Erythronium grandiflorum) would be available in the avalanche chute, mountain sidehill park, and burn shrubfield habitat components.

The mountain sidehill park component had the highest occurrence of biscuit-root of those components available before July. The slabrock component and the alpine complex component became available for digging activity in July. Western bistort (Polygonum bistortoides) was present in the subalpine cirque meadow and the slabrock components.

Comparisons During the Fruit Forage Season (August 1-Den Entry)

Table 6 shows vegetation type rankings for the fruit forage season. The subalpine fir/beargrass-globe huckleberry h.t. ranked the highest of all componments and vegetation types and was significantly greater in fruit-bearing taxa than the second-ranking terrestrial Picea VT (flood plain complex) (M-W p=0.06). There was also a significant difference in the second ranking terrestrial Picea VT and the third ranking subalpine zone burn VT (M-W p=0.06).

Globe huckleberry occurred in three of 28 vegetation types and in all three habitat types. The greatest cover of this food was in the subalpine fir/beargrass-globe huckleberry h.t. (table 7). Open-timbered stands of this habitat type were observed to have the greatest globe huckleberry fruit production of any vegetation type or habitat type. Such productive sites existed as stringers in the Xerophyllum tenax VT of the avalanche chute complex.

Serviceberry was widely distributed among habitat types and habitat components (table 7). The food item reached the highest percent cover and occurrence in the temperate zone burn VT; however, ungulate browsing pressure on this species during the winter appeared to be severe in this type.

The terrestrial Picea VT (flood plain benches) showed the highest observed cover of buffalo-berry (Shepherdia canadensis) of all types. Species of currant (Ribes spp.) and rose (Rosa spp.) had reached the greatest cover in several vegetation types in the riparian zone of the flood plain complex component.

Table 2.--Relationships among component availability, food categories, and foraging season

Habitat component	Monthly availability[1] by foraging season						
	Herbaceous[2]			Fruit[3]			
	May	June	July	Aug.	Sept.	Oct.	Nov.
Flood plain complex	X	X	X	X	X	X	X
Timbered creek bottom	X	X	X	X	X	X	X
Avalanche chute complex	X	X	X	X	X	X	X
Mountain sidehill park	X	X	X	X	X	X	X
Open burn shrubfield:							
Temperate zone	X	X	X	X	X	X	X
Subalpine zone			X	X	X	X	X
Timbered habitat types[4]				X	X	X	X
Subalpine cirque meadow			X	X	X	X	X
Slabrock			X	X	X	X	X
Alpine complex			X	X	X	X	

[1]Availability refers only to snow-free months.
[2]Vegetation, modified stems.
[3]Modified stems, fruit, pine nuts.
[4]Habitat types were not evaluated for herbaceous foraging season.

Table 3.--Vegetation type rankings for the herbaceous foraging season (highest ranking types only; den emergence to July 31)

Rank	Vegetation type	Habitat component	Vegetation type importance value	No. bear foods per preference rank			First month of availability
				1	2	3	
		VEGETATIVE FOOD CATEGORY					
1	Tallgrass/Senecio triangularis	Subalpine meadow	88	0	5	3	July
2	Alnus spp. shrubfield	Avalanche chute complex	61	2	3	6	May
3	Riparian Picea	Flood plain complex	54	1	4	7	May
4	Glade	Timbered creek bottom	40	3	5	8	May
5	Mesic herbaceous fan	Avalanche chute complex	40	4	3	6	May
6	Streamside	Avalanche chute complex	37	4	5	4	May
7	Mesic herbaceous meadow	Flood plain complex	36	1	2	8	May
8	Xeric herbaceous fan	Avalanche chute complex	32	3	1	5	May
9	Xerophyllum tenax	Avalanche chute complex	27	3	1	4	May
10	Closed timber	Timbered creek bottom	14	2	5	8	May
		MODIFIED STEM FOOD CATEGORY					
1	Sand bar	Flood plain complex	5	0	5	2	May
2		Slabrock	4	0	2	4	July
3	Mesic alpine meadow	Alpine complex	3	0	1	4	July
3	Xerophyllum tenax	Avalanche chute complex	3	0	2	4	May
3	Temperate zone burn shrubfield	Burn shrubfield	3	0	4	3	May

Table 4.--Coverage and occurrence of several "key" vegetative food items per vegetation type (percent cover/percent occurrence)

Habitat component	Vegetation type	*Heracleum lanatum*	*Angelica arguta*	*Ligusticum canbyi*	*Osmorhiza occidentalis*	Gramineae/ Cyperaceae	*Equisetum* spp.
Avalanche chute complex	Streamside	8/47	3/43	t/8[1]		8/100	
	Alnus shrubfield	8/52	1/10	1/14	1/15	3/72	
	Mesic herbaceous fan	4/40	1/18		1/36	26/100	
	Xerophyllum tenax	t/23	t/5		2/20	8/60	
	Xeric, warm aspect				t/8	30/100	
	Xeric herbaceous fan	t/9	t/6		5/38	21/81	
Flood plain complex	*Salix* flat	5/73	t/65	t/4	t/8	43/100	5/46
	Mesic herbaceous meadow	2/62	1/92		t/15	41/100	1/77
	Riparian *Picea*	1/63	t/56			15/100	2/59
	Populus trichocarpa	t/25	t/25			30/75	t/25
	Terrestrial *Picea*					7/100	
	Gravel bar					7/74	t/15
	Sand bar	t/7				4/69	
	Xeric graminoid meadow					26/100	
Timbered creek bottom	Glade	t/46	t/46			21/100	6/82
	Closed timber	1/48	2/40			24/100	1/53
Subalpine meadow	Tall grass/*Senecio triangularis*	4/31		2/35	7/50	26/100	
	Hydromesic			t/25		20/100	t/8
	Shortgrass/*Phyllodoce empetriformis* VT					49/100	t/4
Mountain sidehill park	Mixed graminoid					44/100	
	Xeric bunchgrass				t/2	10/90	
Burn shrub-field	Temperate zone		t/1			14/100	
	Subalpine zone		t/7			6/90	
Slabrock						16/100	
Alpine complex	Vegetated rock/talus					5/80	
	Fellfield					14/70	
	Mesic meadow					12/100	

[1] t=<0.5 percent cover.

Table 5.--Percent cover and occurrence of root, corm, and bulb food item per vegetation type (percent cover/percent occurrence)

Habitat component	Vegetation type	*Astragalus* spp.	*Oxytropus* spp.	*Erythronium grandiflorum*	*Polygonum bistortoides*	*Claytonia* spp.	*Hedysarum occidentale*	*Allium* spp.	*Lomatium* spp.
Flood plain complex	Xeric graminoid meadow							t/5	
	Mesic herbaceous meadow	t/23[1]						1/31	
	Sand bar	t/39	2/46					t/54	t/8
	Populus trichocarpa	1/75						t/50	
	Salix spp. flat	t/27						t/15	
	Terrestrial *Picea*	t/4						t/13	
	Riparian *Picea*	t/7						t/15	
	Gravel bar	t/26	t/4					t/4	
Avalanche chute complex	Mesic herbaceous fan								t/4
	Streamside			t/6			t/2		t/2
	Xeric, warm aspect	t/5		t/2					t/27
	Xerophyllum tenax	t/4		t/12			1/28		t/5
	Xeric herbaceous fan							t/6	
Mountain sidehill park	Mixed graminoid			t/12					t/24
	Xeric bunchgrass	t/2		t/32				t/4	t/24
Burn shrubfield	Temperate zone burn shrubfield	t/10		t/5			1/23	t/51	t/25
	Subalpine zone burn shrubfield	t/16		t/13			1/52		
Timbered creek bottom	Glade	t/4						t/8	
	Closed timber	t/11						t/21	
Subalpine meadow	Hydromesic herbaceous			t/17	t/71			t/71	
	Tallgrass/*Senecio triangularis*							t/22	
Slabrock		t/5		1/40	1/39	t/13		t/6	t/21
Alpine complex	Mesic meadow				t/52	t/12			1/48
	Vegetated rock/talus	t/16					t/3		1/32
	Fellfield	t/27							t/40

[1] t=<0.5 percent cover.

Table 6.--Vegetation type rankings for the fruit foraging season (highest ranking types only; August 1 to den entry)

Rank	Vegetation type or habitat type	Habitat component or forest habitat type	Vegetation type importance value	No. food items per preference rank 1	2	3
		FRUIT FOOD CATEGORY				
1	Abies lasiocarpa/Xerophyllum tenax-Vaccinium globulare	Forest habitat type	92	0	1	4
2	Terrestrial Picea	Flood plain complex	47	1	2	3
3	Subalpine zone burn shrubfield	Burn shrubfield	43	1	1	1
4	Abies lasiocarpa/Luzula hitchcockii-Vaccinium scoparium	Forest habitat type	38	0	1	2
5	Temperate zone burn shrubfield	Burn shrubfield	36	4	3	4
6	Xeric herbaceous fan	Avalanche chute complex	26	1	1	0
7	Mesic herbaceous meadow	Flood plain complex	25	5	1	3
8	Populus trichocarpa	Flood plain complex	25	2	1	2
9	Closed timber	Timbered creek bottom	16	6	3	2
10	Mixed graminoid	Mountain sidehill park	14	2	3	3
		MODIFIED STEM FOOD CATEGORY				
1	Sand bar	Flood plain complex	5	0	5	2
2		Slabrock	4	0	2	4
3	Mesic alpine meadow	Alpine complex	3	0	1	4
3	Xerophyllum tenax	Avalanche chute complex	3	0	2	4
3	Temperate zone burn shrubfield	Burn shrubfield	3	0	4	3

Table 7.--Cover and occurrence of "key" shrub food items (percent cover/percent occurrence)

Habitat component or habitat type	Vegetation type	Vaccinium globulare	Amelanchier alnifolia	Vaccinium caespitosum	Cornus stolonifera	Shepherdia canadensis	Sorbus spp.	Rhamnus alnifolia	Vaccinium scoparium	Ribes spp.	Rosa spp.
Flood plain	Xeric, graminoid meadow										t/5
	Mesic herbaceous opening		t/8[1]		2/15[1]	1/23				2/54	8/100
	Sand bar									t/15	3/62
	Populus tricho-carpa				24/75	2/75				t/25	1/100
	Salix flat		t/4			t/4		t/12		5/81	1/77
	Terrestrial Picea		t/17	41/91		91/13					t/4
	Riparian Picea				2/52	t/15				t/26	2/81
	Gravel bar										t/4
Avalanche chute complex	Alnus shrubfield						3/17	t/2		t/22	
	Mesic herbaceous fan			t/13			t/2		t/2	4/33	
	Streamside				t/1		1/8		t/2	3/10	
	Xeric, warm aspect		4/51	t/2			t/1		t/3		
	Xerophyllum tenax		1/26			t/2	1/6	t/1	4/21		
	Xeric herbaceous fan							18/28		3/19	
Burn shrubfield	Temperate zone		9/86		t/3	2/24	t/20		1/5	t/22	t/1
	Subalpine zone	3/13							16/100		t/3
Abies lasiocarpa/ Xerophyllum globulare habitat type		22/97	t/32			1/15	t/35				
Timbered creek bottom	Glade				6/21			t/4		1/57	t/29
	Closed	t/5		t/5	12/37					1/45	1/29
Abies lasiocarpa/ Menziesia ferruginea habitat type		t/92									
Mountain sidehill park	Mixed graminoid	t/6	2/71	t/6	2/6						t/18
	Xeric bunchgrass		1/20								
Subalpine meadow	Hydromesic								t/12		
	Shortgrass/ Phylldoce empetriformis								t/21		
Slabrock									2/19		
Alpine complex	Vegetated rock/talus								1/3		

[1] t=<0.5 percent cover.

Whitebark pine grew at elevations above 2 128 m. Grizzly bears seeking this food item would necessarily travel to habitats at or above this elevation.

DISCUSSION

The Habitat Component System

The habitat system described was developed in two field seasons. Although the major components and vegetation types were sampled and incorporated, expansion of the system would be possible.

Field reconnaissance and vegetation sampling suggested that although specific habitat components and their associated vegetation types could be extrapolated to other parts of the Bob Marshall Wilderness, the areal extent and juxtaposition of components and types could not be extrapolated. Ground reconnaissance and the literature (Habeck 1967; Johnson 1982) suggest that several precipitation zones are present in the Wilderness. The southern portion of the Wilderness is drier than northern portions adjacent to the Swan Range. Plant indicators of relatively moist habitats such as pachistima (Pachistima myrsinites) and queencup beadlily (Pfister and others 1977) were observed much less often in the southern study area than in Gorge, Statium, and Trickle Creeks in the northwestern portion of the Wilderness. If grizzly bear habitat quality is related to precipitation, population densities may be naturally variable within the Wilderness boundaries.

Those vegetation types that provided relatively high cover and occurrence values of key food items were considered superior to those types with lower values. This assumption was corroborated by grizzly bear investigations conducted in more open habitats, where study animals were easily observed. Stelmock (1981) stated that "habitat use during the summer was mainly confined to very specific vegetation types which provided dense cover of favored plant foods. Habitat use patterns closely followed the seasonal variations in quantity and quality of important foods."

Seasonal Ranking of Vegetation Types

The grizzly bear should be considered a "directed forager" because much of its habitat use patterns can be explained in terms of the presence of a few highly favored foods (Knight and others 1984). Thus only "key" grizzly bear foods obtained from the literature were used in the seasonal rankings. These rankings would place the grizzly bear in relatively high-quality habitat even if several unknown food items were not used in the analyses. Grasses and sedges were omitted from seasonal analyses because they tended to mask the importance of other foods, although grasses and sedges should be considered a staple food. Craighead and others (1982) theorized that grasses and sedges are more readily utilized because they are more available and abundant than other plant items.

Herbaceous foraging season.--Grizzly bears would find abundant succulent food plants in the flood plain complex, particularly in the riparian Picea VT and the mesic herbaceous meadow VT. The roots of yellow hedysarum (Hedysarum sulpherescens), however, are not likely an important food item in the study area because only one plant was observed. Such root-digging activity is important to grizzlies in the North Fork of the Flathead River (Singer 1978; McLellan 1982). Greater cover of crazyweed (Oxytropis spp.) was observed on the flood plain benches of the White River (northeast corner of the Bob Marshall) than in the core study area. No digging activity was observed in any flood plain complex types.

The observed quantity of plant foods in the avalanche chutes suggested that they would be an important spring and early component of habitat, especially the Alnus VT and the mesic herbaceous fan VT. The overall forage quality of the avalanche chute complex increased if the chute contained a stream course, was on a northern or western exposure, and was not dominated by a closed canopy of alder (Mace 1984).

Openings in the timbered creek bottoms of the study area (the glade VT) provided high cover values of horsetail, grasses and sedges, and several Umbelliferae. Creek bottom areas with a closed canopy were less productive than glades. It is probable, however, that preferred food items in these timbered sites would be relatively high in protein and moisture content for prolonged periods as compared to more open areas (Graham 1978).

The results of the less intensive alpine vegetation studies correlated well with those of Craighead and others (1982). Herbaceous foods were not abundant in the alpine complex but ranked high in foods that would be dug by grizzlies. No insect concentrations, known to be a summer source of food in several areas (Chapman and others 1953; Servheen 1981; Craighead and others 1982), were observed in the alpine complex of the study area.

Although whitebark pine nuts were not sampled specifically, grizzly bears would find them in abundance during years of good cone crops in the subalpine and alpine zones of the study area. Several scats of unknown bear species, collected in August, contained pine nuts; however, intense high-elevation burns could limit the availability of this food in certain areas, as whitebark pine does not mature for several decades following stand-replacing fire (Fischer and Clayton 1983).

Fruit foraging season.--Midelevation, open-timbered stands on southern exposures showed high fruit production of globe huckleberry. These productive sites often existed within large and south-facing avalanche chutes. Martin (1979)

stated that globe huckleberry is a late-seral or climax, meso-seral fruit producer.

Fruit production and cover values of buffalo-berry were relatively high on open to open-timber benches in the flood plain complex (terrestrial Picea VT). Conversely, virtually no dwarf huckleberry (Vaccinium ceaspitosum) fruit production was noted on these benches during the 2 years of study. Such bench land habitats are exceedingly important to grizzly bears occupying low-elevation areas during the autumn (McLellan 1982).

Those portions of the subalpine zone burns that occurred within the subalpine fir/beargrass-globe huckleberry h.t. showed relatively high cover of globe huckleberry. Burn shrubfields of the temperate zone were especially high in serviceberry cover values. All burns sampled in the temperate zone were of a Douglas-fir h.t. series and burned in 1926 (59 years ago).

Tisch (1961) found the subalpine fir/fool's huckleberry h.t. to be the most productive site for globe huckleberry in the Whitefish Range, MT. The lower cover values of this species in the Bob Marshall may reflect a small sample size (n=12) for this habitat type; however, such north-facing timbered sites appear to be important foraging habitats for grizzly bears during years of low rainfall (Mace and Jonkel 1980).

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GRIZZLY BEAR HABITAT USE, FOOD HABITS, AND MOVEMENTS IN THE SELKIRK MOUNTAINS, NORTHERN IDAHO

Jon A. Almack

ABSTRACT: Grizzly bear (Ursus arctos horribilis) habitat in the Selkirk Mountains of northern Idaho was evaluated during 1983 and 1984. Habitat use, feeding habits, and movements of one adult female grizzly bear were investigated. Twenty habitat component classes were identified for analysis. Forb and shrub seral stages of a large, 18-year-old burn were used more than expected by chance ($P < 0.10$). Timbered components and recent cutting units were used less than expected. Food items were identified by scat analysis and direct observation of foraging grizzly bears. Eight previously undocumented food items were identified. Daily linear movements averaged 3.0 km, ranging from virtually no movement for a period of 3 weeks before denning to a long-distance trek of 45.7 km in an 18-hour period. Annual home ranges for 1983 and 1984 measured 195 km^2 and 609 km^2, respectively.

INTRODUCTION

Grizzly bears occur throughout the Selkirk Mountains of northern Idaho and northeastern Washington; however, data from the Selkirk Mountains Grizzly Bear Ecosystem (SMGBE) have been insufficient to allow the estimation of population parameters, habitat requirements, and accurate delineation of grizzly bear range (USDI 1982). Wright (1909) first documented the presence of this population in his historical account of hunting treks into the Selkirk range. Sutliff (1933) also chronicled a Selkirk grizzly bear hunt, noting a spring concentration of bears in the area. The most recent known kill occurred illegally near Priest River in 1983.

Scientific review of the Selkirk population was virtually absent until Layser's (1972, 1978) discussions of confirmed observations and sign. Zager (1981, 1983) conducted a habitat survey of the SMGBE to determine if grizzly bear habitat components and foods were present and capable of supporting a viable grizzly bear population.

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To obtain additional information on the Selkirk grizzly bear population and its habitat, Idaho Department of Fish and Game, Washington Department of Game, USDA Forest Service, USDI Fish and Wildlife Service, Idaho Cooperative Wildlife Research Unit, University of Idaho, and British Columbia Fish and Wildlife Branch provided funding and materiel support for a 2-year research project. The objectives of the study were to determine seasonal grizzly bear habitat use, identify seasonal food habits, determine individual home ranges, and delineate population distribution.

STUDY AREA

The SMGBE includes the southern portion of the Selkirk range in Washington and Idaho, encompassing approximately 2 590 km^2 (fig. 1). The rugged, bedrock-exposed landscape is covered by a mosaic of dense coniferous forest, old burns, and cutting units. Elevations range from 518 m to just above 2 330 m. Precipitation ranges from 85 to 95 cm annually; snow depths average 1 to 6 m. Timber management dominates the area; virtually the entire SMGBE falls under Forest Service and Idaho Department of Lands administration.

METHODS

By combining over 220 habitat component complexes mapped by the Forest Service in 1983 and 1984, I identified 20 component classes for analysis:

Habitat component	Description
A Alder shrubfield	Dense shrubfield dominated by alder with Rocky Mountain maple. Canopy cover 80 + percent.
B Mixed shrubfield burn	Open shrubfield dominated by mix of huckleberry, elderberry, fool's huckleberry, mountain-ash. Canopy cover 30 to 50 percent.
C Mixed shrubfield snowchute	Dense shrubfield dominated by mix of species with cover to 100 percent. Maintained by violent, infrequent snow avalanches.

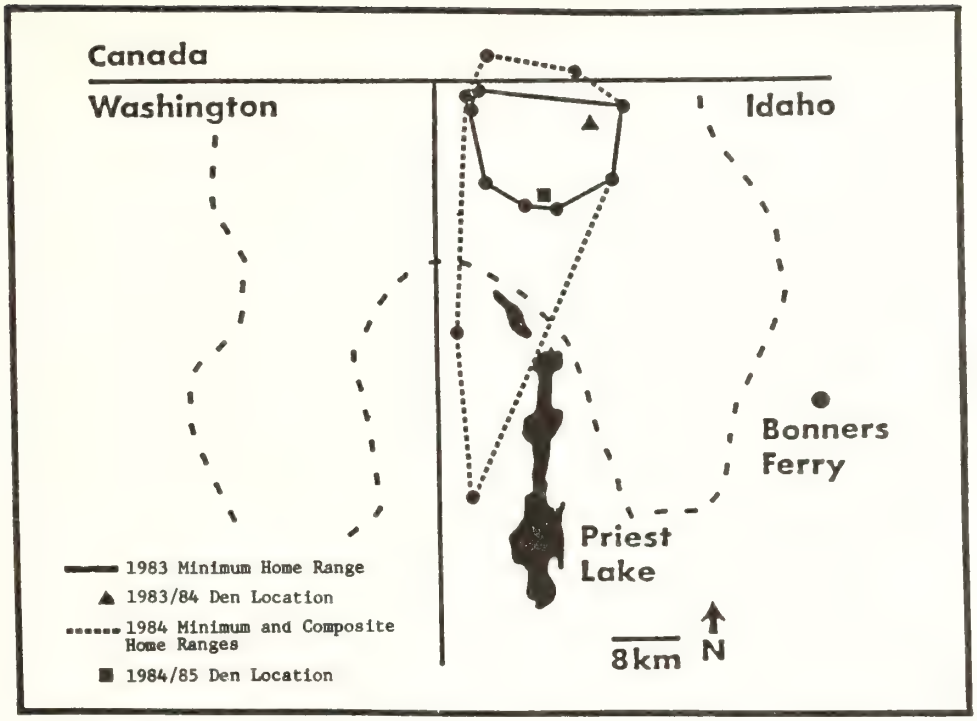


Figure 1.--1983 and 1984 minimum home ranges for grizzly bear U867. The 1983 range (195 km^2) included period from June 4 capture to November 5 den entry. The 1984 range (609 km^2) included period from April 22 den emergence to November 5 den entry.

Habitat component	Description
D Drainage forbfield	Small, succulent forbfield at base of rock outcrops, cirque headwalls, and moraines. Maintained by snowmelt and rain drainage off of rock.
E Timbered mixed shrubfield	Shrub-dominated understory with tree canopy of 30 to 60 percent.
EE Forbfield burn	Early seral forb stage following natural fire.
F Forbfield cutting unit	Early seral forb stage following timber harvest.
FF Open-timbered grass	Grass-dominated understory with tree canopy 30 to 60 percent.
G Grass sidehill park	Open, grass-dominated park; often along ridges or on upper slopes.
H Mixed shrubfield	Shrubfield with <30 percent tree canopy codominated by mix of shrubs.
K Rock	Nonvegetated rock, slabrock, talus, scree, boulders, cliffs, outcrops.
M Marsh	Sedge-dominated with slow-moving or standing water.
NC New cutting unit	Recent timber harvest site with little or no vegetation regeneration.
R Riparian stream-bottom	Lush growth along streams; includes open and timbered sites.
U Mixed shrubfield	Mixed species seral shrub cutting unit stage following timber harvest.
V Huckleberry shrubfield	Shrubfield dominated by canopy of >40 percent huckleberry, <30 percent tree cover.
W Wet meadow	Grass- and sedge-codominated meadow.
X Beargrass sidehill park	Open, beargrass-dominated park; often along ridgetops or on upper slopes.
Z Dry meadow	Open, grass-dominated meadow; often created by physical disturbance.
0 Closed timber	Tree-dominated site with canopy >60 percent.

Table 1.--Interpretation of habitat component use versus availability results for grizzly bear U867[1]

Habitat component	Habitat use[2]			Total
	Spring	Summer	Fall	
Alder shrubfield	<	<	=	=
Mixed shrubfield burn	=	>	=	>
Mixed shrubfield snowchute	=	=	=	=
Drainage forbfield	=	=	=	=
Timbered mixed shrubfield	=	<	<	<
Forbfield burn	=	>	<	>
Forbfield cutting unit	<	=	=	=
Open-timbered grass	<	<	<	<
Grass sidehill park	=	=	<	=
Mixed shrubfield	=	=	=	=
Rock	=	=	=	=
Marsh	=	=	=	=
New cutting unit	<	<	<	<
Riparian streambottom	<	=	=	=
Mixed shrubfield cutting unit	=	=	=	=
Huckleberry shrubfield	=	=	<	=
Wet meadow	=	=	=	=
Beargrass sidehill park	<	=	=	=
Dry meadow	<	=	=	=
Closed timber	<	<	=	<

[1]N (use) = 272 radio locations.
[2]N (availability) = 307 random locations.
[2]Habitat use symbols:
< Use significantly less than availability ($P < 0.10$).
> Use significantly greater than availability ($P < 0.10$).
= No significant difference detected between use and availability ($P > 0.10$).

Studies in the SMGBE (Zager 1981; Demers 1983; Robinson and Riley 1984) and Montana (Jonkel 1982; Christensen and Madel 1982) provided general descriptions of each habitat component class (Almack 1985).

Using these classes as a framework, I obtained baseline habitat use data for the SMGBE from daily radio monitoring and direct observation of an adult, female grizzly bear (U867). I followed the sampling design and analyses presented by Marcum and Loftsgaarden (1980). This method identifies the number of radio and random locations found in each habitat component class within the composite home range. Proportions of seasonal habitat use (radio locations) and availability (random locations) are then compared by analysis of chi-square ($P < 0.05$) and modified Bonferroni z ($P < 0.10$) statistics. Spring availability proportions may be slightly inflated, due to variable snow cover of components at higher elevations.

Distances from all 272 radio locations and 307 random locations measured to the nearest different habitat component, water, road, and trail provided further habitat use information. I grouped distance measurements into three classes: close (< 100 m), mid (100-500 m), and far (> 500 m).

Scat analysis and direct observation of foraging grizzly bears provided data for a partial list of grizzly bear food items. Differentiation of scats by bear species followed the methods of Hamer and Herrero (1980), excluding diameter and amorphous volume as positive identifiers. I classified a scat as "grizzly bear" only when I saw the scat dropped or found the scat at a visual observation site or close-distance radio location, where other direct evidence of grizzly bear activity was apparent.

I determined the length of daily movements for the radio-collared female by measuring linear distances on a map (Mech 1983). Delineation of her 1983 and 1984 home ranges followed the procedures described by Mohr (1947). Area polygons formed by 272 independent radio locations depicted minimum annual and composite home ranges (Russell and others 1979).

RESULTS AND DISCUSSION

Habitat Use

I rejected the null hypothesis that U867 used habitat components in proportion to their availability. Both total and seasonal comparisons showed significant differences between component use and availability ($P < 0.05$) (table 1).

Overall, U867 used mixed shrubfield burn and forbfield burn habitat components significantly more than expected ($P < 0.10$). She used timbered mixed shrubfield, open-timbered grass, new cutting unit, and closed timber components less than expected ($P < 0.10$).

Studies have indicated that grizzly bear spring range is often limited by prevailing snow cover and minimal plant productivity during early phenological stages (Jonkel 1982; Craighead and Mitchell 1983). Therefore, I anticipated use of important spring components, such as wet meadows, marshes, and snowchutes, to be greater than their availability. However, U867 used no component more than expected during spring. No significant differences ($P > 0.10$) were indicated between use and availability proportions for mixed shrubfield burn, mixed shrubfield snowchute, drainage forbfield, forbfield burn, grass sidehill park, mixed shrubfield, rock, marsh, mixed shrubfield cutting unit, huckleberry (Vaccinium spp.) shrubfield, and wet meadow habitat components. She used alder (Alnus sp.) shrubfield, forbfield cutting unit, open-timbered grass, new cutting unit, riparian streambottom, beargrass (Xerophyllum tenax) sidehill park, dry meadow, and closed timber components less than expected ($P < 0.10$).

Summer results closely paralleled field observations. Mixed shrubfield burn and forbfield burn habitat components showed greater use than expected during summer ($P < 0.10$). U867 often used burn components to the near exclusion of other classes, feeding nearly 50 hours on huckleberry and elderberry (Sambucus racemosa). She used alder shrubfield, timbered mixed shrubfield, open-timbered grass, new cutting unit, and closed timber components less than expected ($P < 0.10$).

U867 used no fall component more than expected ($P > 0.10$). She used timbered mixed shrubfield, forbfield burn, open-timbered grass, grass sidehill park, new cutting unit, and huckleberry shrubfield components less than expected ($P < 0.10$).

Field observations indicated a shift from summer to fall component use. She fed on grass and forb roots in clearcuts and selection cuts during October each year; however, cutting units did not show more fall use than expected ($P > 0.10$). During this same period, daily activity decreased to a predenning lethargy phase. This inactive period may have overshadowed apparent heavy use of cutting units in early fall.

Sixty-three percent of the total radio locations fell within 100 m of the nearest habitat component. Similar results were noted for seasonal measurements. Of the total number of radio locations, 68 percent occurred nearest to timber and shrubfield components. U867 may have selected these sites for the security cover provided by the dense vegetation (Zager 1980; Jonkel 1982).

U867 remained near water more than expected by chance ($P < 0.05$), with 27 percent of her total radio locations within 100 m of water and 79 percent within 500 m (table 2). Seasonal analyses failed to show significant differences between the use and availability of water distance classes ($P > 0.10$).

The distribution of water did not appear to limit her use of any area. Perhaps this analysis indicates a preference for moist site foods, or the abundance of moist sites, rather than a direct water requirement.

No significant differences ($P > 0.10$) were noted between distances measured to roads from radio and random locations. Sixty-four percent of the total radio locations occurred in the > 500-m distance class. Seasonal results varied for each road distance class (table 2). These data result from the distribution of the road system in the SMGBE. At least one road penetrates each major drainage in U867's composite home range; however, seasonal activity centered in areas of low road density.

Total and summer analyses of distance to nearest trail data indicated greater than expected use of the < 100-m and 100- to 500-m classes ($P < 0.10$) (table 2). The > 500-m distance class was used less than expected for these two periods ($P < 0.10$). Spring and fall results failed to show significant differences between the use and availability of trail distance classes ($P > 0.10$). Few maintained trails occurred within U867's composite home range, hence the large number of radio locations in the > 500-m distance class. Many of the trails documented for this analysis are actually overgrown fire access roads showing continued use as game trails.

Food Habits

The food habits of U867 were similar to those of grizzly bears in other ecosystems; however, I recorded eight food items undocumented in other study areas:

Species	Structures observed[1]
Direct observation food items	
Camponotus sp. ants	E
Carex spp.	Fl, Lvs
Equisetum arvense	Fl, St
Formica sp. ants	E
Graminoid spp.	Fl, Lvs, R
Gymnocarpium dryopteris	Lvs
Heracleum lanatum	St
Luzula hitchcockii[2]	Fl, Lvs, R, St
Sambucus racemosa	Fr
Streptopus amplexifolius[2]	Lvs, St
Taraxacum officinale	Lvs, St
Trifolium repens	Fl, Lvs, St
Trillium ovatum[2]	Fl, St
Vaccinium spp.	Fr, Lvs, St

Table 2.--Interpretation of seasonal distance class use versus availability for grizzly bear U867[1]

Distance to nearest:	Distance class use[2] Close < 100 m	Mid 100-500 m	Far > 500 m
Water			
Spring	=	=	=
Summer	=	=	=
Fall	=	=	<
Class total	>	=	=
Road			
Spring	=	<	=
Summer	=	=	=
Fall	=	>	=
Class total	=	=	=
Trail			
Spring	=	=	=
Summer	>	>	<
Fall	=	=	=
Class total	>	>	<

[1]N (use) = 272 radio locations.
Spring = 62 radio locations.
Summer = 132 radio locations.
Fall = 78 radio locations.
N (availability) = 307 random locations.

[2]Distance class symbols:
< Use significantly less than availability ($P < 0.10$).
> Use significantly greater than availability ($P < 0.10$).
= No significant difference detected between use and availability ($P > 0.10$).

Species	Structures observed[1]
Dig food items	
Angelica arguta[2]	R
Claytonia lanceolata	R
Clintonia uniflora[2]	R
Erythronium grandiflorum	Fl, R, St
Graminoid spp.	R
Lomatium sp.	R
Mitella breweri[2]	R
Osmorhiza spp.	R, St
Sambucus racemosa	R
Spermophilus columbianus	E
Tiarella trifoliata[2]	R, St
Viola glabella[2]	Lvs, R, St

The analysis of 234 scats and direct observation of foraging grizzly bears provided food lists for the SMGBE (table 3).

[1]E = entire organism
Fl = flower
Fr = fruit
Lvs = leaves
R = root
St = stem.

[2]Food item not noted in literature.

During spring, U867 fed on sedges (Carex spp.), horsetail (Equisetum spp.), clover (Trifolium spp.), grasses, and roots of western spring beauty (Claytonia lanceolata), glacier lily (Erythronium grandiflorum), and biscuit-root (Lomatium spp.). She used wet meadows, marshes, and moist cirque basins extensively during this season.

She fed in mixed shrubfields of a large burn during summer. Huckleberry and elderberry fruits, horsetail, licorice-root (Ligusticum spp.), and ants (Camponotus sp., Formica sp.) were common food items. Shrub fruits dominated her summer diet, although at times she fed almost exclusively on forbs and grasses.

During fall in 1983, U867 dug in old (greater than 2 years) clearcuts and selection cuts for roots of grasses, Brewer's mitella (Mitella breweri), and coolwort foamflower (Tiarella trifoliata). However, in 1984, she excavated cutting units exclusively for roots of first-season growth elderberry and desiccated sweet-cicely (Osmorhiza spp.). She also clawed and rolled logs for ants and earthworms (Class Oligochaeta).

Table 3.--Grizzly bear food items identified by scat analysis (N = 34 scats)

Species	Constancy	Structures observed
	Percent	
Shrubs	10.6	
Lonicera sp.	5.9	Lvs, R
Oplopanax horridum	5.9	Fr, S
Sambucus racemosa	5.9	Lvs, R, St
Vaccinium membranaceum	41.2	Fr, Lvs, S, St
Vaccinium scoparium	8.8	Lvs, S
Vaccinium spp.	20.6	Lvs, S, St
Forbs/ferns	60.0	
Equisetum spp.	55.9	St
Ligusticum canbyi	17.6	Lvs
Ligusticum sp.	23.5	Lvs
Lomatium sp.	11.8	Lvs
Osmorhiza chilensis	5.9	Lvs, R, St
Osmorhiza sp.	17.6	Lvs, St
Streptopus amplexifolius	5.9	Fr, S
Trifolium sp.	8.8	Fl, Lvs, St
Unknown fern sp.	2.9	Lvs
Unknown seed	5.9	S
Grass/grasslikes	16.2	
Carex sp.	38.2	Fl, Lvs
Graminoid spp.	85.3	Fl, Lvs, R, St
Luzula hitchcockii	11.8	Lvs, R (?)
Animal	15.2	
Camponotus sp. ant	11.8	E
Formica sp. ant	17.6	E
Odocoileus sp.	5.9	B, H, Hf
Spermophilus columbianus	11.8	B, C, H, T
Ursus americanus	2.9	H
Ursus arctos	20.6	H
Unknown sp. beetle	5.9	E, L, W
Unknown sp. bone	5.9	
Unknown sp. hair	8.8	
Unknown sp. insect wing	2.9	
Unknown sp. worm	2.9	

[1] B = bone
C = claw
E = entire organism
Fl = flower
Fr = fruit
H = hair
Hf = hoof
L = leg
Lvs = leaves
R = root
S = seed
St = stem
T = teeth
W = wing.

Dens

In 1983, U867 denned in a northeast-facing, natural rock cave at 1 902 m. The cave measured 9.4 m deep and opened at the base of a rock outcrop that protruded into a timbered mixed shrubfield. The entrance measured 86 cm wide and about 80 cm high.

She used white rhododendron (Rhododendron albiflorum) and fool's huckleberry (Menziesia ferruginea) stems to form a nest located about 5.4 m from the entrance and measuring 1.6 m in diameter. The nest site had apparently been used before, as evidenced by 30 cm of decayed shrub stems and beargrass leaves that lay under the most recent nest material.

I found two scats behind the nest. Both scats were moldy and densely compacted; each contained grizzly bear guard hairs and smooth woodrush (Luzula hitchcockii) leaves.

A rock shelf, 1.1 m wide, extended for about 7.6 m in front of the den. A natural mat of soil and smooth woodrush covered the shelf and extended down slope into a timbered mixed shrubfield of white rhododendron, fool's huckleberry, and huckleberry. U867 had chewed off many of these shrubs, leaving only 10 to 15 cm of the stems remaining above ground. I found chewed shrubs up to 21 m from the den. Five daybeds were located on this shelf, and several trees showed deep claw marks to a height of about 2.5 m.

In 1984, U867 also denned in a natural, rock cave. The den lay between two active snowchutes at 1 890 m on the northeast-facing headwall of an east-facing cirque basin. The cave opened at the base of a rock outcrop in a mixed shrubfield/rock habitat component complex. The entrance was very exposed and measured 133 cm high and 90 cm wide.

The nest measured 137 cm in diameter and was located at the rear of the cave. Chewed stems of mountain-ash (Sorbus spp.) and huckleberry, along with leaves of smooth woodrush and sedge, served as nest material. Most of this material had been scraped from the nest and swept out of the den. I found only three shrubs near the den that showed any evidence of chewed stems.

I found three small scats just inside the cave. They were not densely compacted, as were the 1983-1984 den scats. All three scats contained unidentified vegetal debris.

Den entry both years occurred on November 5. Den emergence was on April 22, 1984, and during the week of May 10, 1985.

Daybeds

I located 10 grizzly bear daybeds in the SMGBE; eight of these belonged to U867. Daybed No. 1 lay under a lone, mature subalpine fir (Abies lasiocarpa) within a grass sidehill park. I located two scats within 1 m of the bed. Both scats measured approximately 8 cm in diameter and

3 L in volume. Each scat contained over 90 percent grass and a trace of licorice-root leaves.

U867 located Daybed No. 2 next to an uprooted stump, associated with ground squirrel (Spermophilus columbianus) digs in a mixed shrubfield burn. This bed measured about 82 cm in diameter and 76 cm deep and contained four alternated layers of loose soil and grass leaves. Radio telemetry indicated that she used this site several times, perhaps adding a fresh layer of soil and grass for each occupancy.

Daybeds No. 3 to 7 lay on the shelf in front of her 1983-1984 cave den. Each bed measured about 90 cm in diameter. Twigs of white rhododendron and fool's huckleberry lined two of the beds; the others lay directly on a mat of smooth woodrush. I cannot document when she used these daybeds.

Craighead and Craighead (1972a, 1972b) and Craighead (1979) noted grizzly bear use of daybeds at the den site immediately prior to denning. Servheen (1981) observed similar use of den site daybeds. He also postulated that grizzly bears may use dens and associated daybeds during the summer to escape daytime heat, which may be the case here. During this July examination, ambient temperatures differed from 6.7 °C in the cave, to 20.0 °C on the shelf outside.

U867 used two daybeds immediately before denning in 1984. After feeding in a clearcut about 100 m down slope, she located Daybed No. 8 on the edge of a small alder shrubfield. She remained in this south-facing bed during a severe overnight snowstorm. The unlined bed lay between two naturally exposed roots on the uphill side of a large Engelmann spruce (Picea engelmannii). A scat packed with sweet-cicely and elderberry roots lay about 5 m from the bed.

She remained at Daybed No. 9 for 15 days, until moving to her den. This bed lay on a natural mat of sedges against the uphill side of a large mountain hemlock (Tsuga mertensiana). Snow measured about 1 m at the bed site. No scats or evidence of feeding were noted near the bed.

Daybed No. 10 lay about 0.5 m from the entrance to her 1984-1985 cave den. Measuring 50 cm in diameter and formed on a natural mat of smooth woodrush, the bed covered the top of a flat boulder. I found no scats near this daybed, but I noted extensive digs for glacier lily within 10 m of the site.

Movements

The mean daily linear movement for U867 measured 3.0 km. Daily movements ranged from 0 to 45.7 km, including periods of virtually no movement before denning and one long trek of 45.7 km to a feeding site. Seasonally, her daily movements averaged 2.8 km for spring, 3.7 km for summer, and 2.4 km for fall, with no significant differences noted ($P > 0.05$). Almack (1985) described several individual movements in detail.

Radio location analysis showed no significant differences in seasonal use of aspects ($P > 0.05$). She remained between 1 400 and 1 700 m elevation, except during May, when she was located at 850 m for about 7 days.

Home Range

Annual home ranges for U867 during 1983 and 1984 measured 195 and 609 km^2, respectively (fig. 1). Her composite home range duplicated the 1984 annual range.

The composite range measured larger than those calculated for most females in other study areas. Both Servheen (1981) and Jonkel (1982) reported female home ranges in northwestern Montana varying from 15 to 136 km^2. Aune and Stivers (1982) reported female ranges from 31 to 450 km^2 on the Rocky Mountain Front in north-central Montana. In Canada, Russell and others (1979) reported several large female home ranges from Jasper National Park; the largest of these measured 532 km^2. One of the largest female home ranges, documented in Yellowstone National Park by Knight and Blanchard (1983), measured approximately 900 km^2.

Russell and others (1979) postulated that a young female (4 to 9 years old) may explore a larger home range to optimize her chances for breeding and to locate a "core range" suitable for rearing cubs. This idea provides a plausible explanation for the size of U867's 1984 home range.

All of her long-distance movements (> 15 km), with the exception of fall movements to den sites and summer movements resulting from human disturbance, occurred from late May to late June, during the breeding season. She also used a much smaller area during summer and fall in 1984.

This smaller "core" area contained approximately 65 percent of her radio locations and measured about 45 km^2. Mostly located within a large burn, this area contained a rich food supply, consisting of productive forbfields, huckleberry and elderberry shrubfields, and an abundance of ground squirrels, marmots (Marmota caligata), and ants. She emerged from her 1984-1985 den about May 13 with two cubs.

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THE SELWAY-BITTERROOT ECOSYSTEM AS GRIZZLY BEAR HABITAT

Dan L. Davis, Wayne E. Melquist and Dean Graham

ABSTRACT: The Selway-Bitterroot Grizzly Bear Ecosystem (SBGBE) is one area described by the Grizzly Bear Recovery Plan as suitable for re-establishing a viable grizzly bear population. Historical evidence indicates that the area once was occupied by grizzly bears with the last confirmed report in 1956. Factors that may have been responsible for the virtual disappearance of the bear are discussed. Management recommendations for the SBGBE are also suggested.

INTRODUCTION

The Grizzly Bear Recovery Plan describes an area centered around the Selway-Bitterroot Wilderness as suitable for recovering a viable grizzly bear (Ursus arctos horribilis) population (U.S. Department of the Interior, Fish and Wildlife Service, 1982). This undefined area is referred to as the Selway-Bitterroot Grizzly Bear Ecosystem (SBGBE). Of the six ecosystems identified in the Plan, the SBGBE received one of the lowest priorities because (1) the area had little or no baseline data on grizzly bear populations or habitat, (2) potential conflicts due to land development would be minimal because most of the area is wilderness, (3) personnel and dollars were limited and it would require excessive expenditures to bring the data base up to par. For these reasons, the Plan did not identify recovery goals and occupied habitat for the area.

A recovery plan goal for the SBGBE was to secure, maintain, or reestablish a viable population of grizzly bears. Specific objectives were to (1) determine the present status of the grizzly bear population, (2) determine the space and habitat necessary to support a viable population, and (3) define the appropriate actions necessary to develop a more refined recovery plan. The U.S. Department of Agriculture, Forest Service, in cooperation with the Idaho Department of Fish and Game and Montana Department of Fish, Wildlife, and Parks, was given the lead responsibility for funding and meeting the specific objectives.

The purpose of this paper is to document reports of grizzly bear observations on the SBGBE and to evaluate and discuss grizzly bear habitat and conditions.

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DESCRIPTION OF THE AREA

The SBGBE is approximately 60 miles southwest of Missoula, MT, in north-central Idaho (fig. 1). It is surrounded by lands managed by the Clearwater, Nezperce, and Bitterroot National Forests. An extensive trail system provides access within the Wilderness. Potential grizzly bear habitat within the three National Forests is remote and undeveloped. Topography is rugged, with elevations ranging from 2,000 to 10,000 ft. Glaciers moved through most of the area, leaving many deep, U-shaped valleys. Alpine meadows and cirque lakes are common. The mountains within this area consist of a granite rock representing the northern extension of the Idaho Batholith (Lindgren 1904). Coniferous vegetation is interrupted by a mosaic of extensive granite slabs, boulder fields, talus slopes, meadows, and avalanche chutes. The geology, geography, climate, and soils of this area have been described (Arno 1970; Lackschewitz 1970; Habeck 1972; and Smith 1976).



Figure 1.--Geographical location of the Selway-Bitterroot Wilderness, ID.

The climate varies considerably but can be generally described as humid or simihumid. The average annual precipitation at 3,000 ft is 43 inches and occurs primarily as snowfall from October through June. Rainfall is common in late spring and early summer, usually decreasing to near drought conditions in July and August. At higher elevations and on northerly slopes, snowpack may remain well into late summer.

DISCUSSION

Historical Perspective

Lewis and Clark were the first explorers to contribute factual information about the grizzly bear and its habitat in Idaho (Burroughs 1961; Layser and others 1979). Expedition members reportedly killed six grizzlies in the Clearwater Valley near Kamiah in 1806. Wright (1909), a skilled hunter and naturalist, found that the bears were relatively common in the Clearwater area in the 1890's. During one episode he reported killing five grizzly bears on the Clearwater. On another occasion, late in the fall of 1981, two hunters from Spokane killed 13 grizzlies during a single bear hunt in the "Bitterroot region."

Merriam (1922) defined the boundaries of grizzly bear range in Idaho and described the habitat there as one of the grizzly bear's last strongholds. He indicated that the bears were "fairly plentiful" in extreme northern Idaho but were confined to the Bitterroot, Clearwater, Lolo, and Salmon River Mountains in the Bitterroot Range. Moore (1984), a trapper and retired Forest Service employee, reported encounters with grizzlies in 1930 and 1931. He also described earlier reports of grizzlies being trapped and shot by others. According to Moore, the last documented sign of grizzly bears was recorded in the mid-1940's by Parsell, a Forest Service Ranger on the Selway. Melquist (1985) analyzed 88 reports of grizzly bears, including the reported killing of a grizzly on the upper Lochsa River in 1956 by District Ranger Puckett.

Historical information indicates the grizzly bear once occupied the SBGBE; one can infer from these reports that the habitat must have been sufficient in quality and quantity to support a viable grizzly population. What, then, caused grizzlies to virtually disappear from the SBGBE?

Fire

Fire, which has burned the SBGBE area for thousands of years, undoubtedly played a major role in shaping and creating quality bear habitat. In his field studies, Habeck (1972) could not find any area "that did not reveal direct evidence of past fire disturbance...even in the oldest forest communities encountered, and in communities at all elevations." Frequent fire has even been documented in the high-elevation spruce/fir zone at, and above, timberline (Habeck and Mutch 1973). Leiberg (1900) reported that large amounts of the Selway-Bitterroot Wilderness burned between 1719 and 1898. Habeck (1972) reported large wildfires in 1910, 1919, and 1934 that burned millions of acres.

In the 1930's, the Forest Service initiated an extremely effective fire prevention and control program that has significantly reduced fire occurrence. From 1934 to 1970 only 12,000 acres burned. Habeck (1972:29) stated that "the extent of fire reduction has been significantly high for a sufficient number of years so that one must assume that there has been or is an environmental impact imposed on the SBW forest ecosystems that requires clear recognition and description."

Fisheries

Another important resource of the SBGBE was the chinook salmon (Oncorhynchus tshawytscha) fishery. Wright (1909) considered the grizzlies of the Bitterroot area to be skilled at fishing and noted that the bears appeared to depend upon these fisheries for at least 2 months of the year. Before 1927, there was a significant run of spawning chinook in the SBGBE. In 1927, however, Inland Power and Light Company constructed a dam across the Clearwater River at Lewiston, ID, to generate electricity and build a lake that could be used to boom logs for the new Potlatch mill. Fish ladders were included in the construction but failed to function properly, so the 35-ft-high obstruction virtually eliminated the upstream chinook fishery.

Biologists have suggested that the loss of the anadromous fishery was central to the disappearance of grizzlies from the SBGBE; however, because the grizzly bear is very adaptable and inhabits areas without a major anadromous fishery, the impact may have been only short term. Grizzlies have survived in the nearby Cabinet-Yaak and Selkirk ecosystems without anadromous fish runs. Undoubtedly, however, the loss of this important food source did come at a time when many other pressures were being imposed on the grizzly bear. Collectively, these changes could have had a significant influence.

Grazing

The large fires encouraged the growth of vegetation conducive to grazing of domestic livestock, and homesteaders from the Selway, Clearwater, and Bitterroot valleys were quick to take advantage of this newly created resource. Space (1979) reports that sheep grazing steadily increased in the early 1900's and peaked around 1935 when 35,000 sheep were found in the area. Grizzly bears presumably foraged on preferred vegetation of burned areas and at times preyed on livestock. Stockmen reportedly feared the grizzly and killed every bear they encountered. Grizzlies were also killed and trapped to protect big game. Moore (1984) reported that trappers near the turn of the century killed 25 to 40 grizzlies annually in the Bitterroot Mountains.

Most herbaceous grizzly foods are also listed as forage plants for domestic livestock (U.S. Department of Agriculture, Forest Service 1969). Livestock using grizzly habitat prefer foods important to grizzlies (Mealey and others 1977; Schallenberger 1976). Mealey (1977) reported that domestic livestock graze important wet areas much more efficiently and occur in greater densities than grizzlies do. The subsequent increased foraging and trampling of vegetation can reduce or eliminate the use of these areas by grizzlies. This direct competition for high-quality forage areas and the killing of bears that interfere with grazing activities thus significantly affect grizzly habitat.

CURRENT SITUATION

Observations

Jonkel (1981:2) has recognized the potential for grizzly bear recovery in the SBGBE. After reviewing past reports, he concluded that "there seems little doubt that the Bitterroot Range and the Selway-Bitterroot area contains a small number of grizzlies." During 1984, Melquist (1985) conducted a preliminary survey in the Clearwater National Forest that failed to provide actual evidence of grizzly bears, but his analysis of 88 reported grizzly bear observations from the same area for the period 1900 to 1984 indicated that circumstantial evidence was enough to conclude that a few grizzlies probably occupy the area, at least as temporary residents.

Eight of the 88 reported observations were classified as kills; the most recent was in 1978. Although two of the eight were classified as confirmed kills, one in 1909 and the other in 1956, further investigations suggest that there may be no material evidence to substantiate these reported kills; therefore, confirmation remains questionable.

Ten of the 88 reports were of sows accompanied by cubs. Six of these reported observations were in the 1970's and three during the 1980's. Following analysis of these reports, Melquist concluded that one or more reproductive females may reside in the area, but he pointed out that the data were neither conclusive nor convincing. Additional reports from the Clearwater National Forest are being evaluated, and survey efforts are now extending into the Nezperce National Forest and SBGBE.

Fire

Fire management policies for the Selway-Bitterroot Wilderness changed significantly in 1979. Approximately 1.24 million acres are now managed under a fire plan that will allow lightning fires to play a more natural role in shaping and perpetuating the wilderness ecosystem (Forest Service 1979). Additional policy changes as recent as January 1985 allow the use of both natural wildfire and prescribed fire in wilderness under certain circumstances (Forest Service 1985). These changes will undoubtedly benefit grizzly bear habitat within the SBGBE, as most of the preferred forage species west of the Continental Divide are created and rehabilitated by wildfires (Mealey 1977). Mealey further states that burns in this region are probably the single most important grizzly habitat component. Since 1979, approximately 30,000 acres have been burned under management prescription. At this rate, a significant portion of the SBGBE could become rehabilitated grizzly bear habitat in the foreseeable future.

Habitat

To properly address the recovery plan's second objective of determining the space and habitat necessary to support a viable grizzly population, one must intensively evaluate and map habitat components. Scaggs (1979) suggests that an area could be evaluated for its suitability as grizzly bear habitat even when bears are absent. His research in the SBGBE was to describe and evaluate the vegetation of a 40-mi^2 area and determine its suitability as grizzly bear habitat. Scaggs stated that "the area rated very good as potential grizzly bear habitat." He further suggested that the subalpine zone, comprising 45 percent of the study area rated as "superior" grizzly habitat. The remaining 55 percent was classified as a temperate zone which rated as "good." He also indicated that the study area was representative of habitat found throughout the Bitterroot Mountains.

If Scaggs is correct, a substantial amount of the SBGBE may be suitable grizzly bear habitat. Further habitat analyses are clearly necessary, however. Funding to continue this type of habitat evaluation for SBGBE has recently become available. For fiscal year 1985, $20,000 (4 percent) of the regional grizzly bear budget has been allocated to the SBGBE. During the 1985 field season, researchers will try to determine whether grizzly bears are present by collecting and evaluating all grizzly reports. To enhance the credibility of "probable" and "highly probable" reports (Melquist 1985), they will conduct some aerial surveys. Because of limited funding, however, only a cursory evaluation of grizzly habitat components can be made at this time.

Fisheries

Hydroelectric development eliminated 50 percent of the chinook fishery habitat. The remaining habitat available for production is at approximately 80 percent of its potential because of impacts associated with logging, road building, and mineral exploration. Also, the present chinook population is only at 15 percent of potential. Continued impacts on the chinook fishery are anticipated; however, this fact alone would probably not preclude the SBGBE from supporting a viable population of grizzly bears. Fishery recovery would certainly enhance bear habitat.

Grazing

Livestock grazing in the SBGBE is negligible, and most grazing is by horses used for guide and outfitting services during hunting season. Only a small amount of cattle and sheep grazing occurs in the area. The trend is to phase out or relocate the remote cattle allotments because they are costly to operate and the range is transitory. Livestock grazing is therefore not anticipated to significantly affect recovery of the grizzly bear population.

Recreation

The elk population has dramatically increased in the SBGBE because of the effects on habitat of large wildfires in the early 1900's and the establishment of refuges in the portions of the area. Refuge designation was discontinued once populations could sustain an annual hunting harvest. Hunter recreation use has risen in conjunction with the elk population. A significant increase in nonhunting recreation such as fishing and hiking has also occurred. All types of recreational use are projected to increase. Compared to the Yellowstone or Glacier ecosystems recreational use in the SBGBE is very low. This

relatively low level of recreational use would minimize potential human/bear conflicts.

Public Information/Education

The only effort to inform the public about grizzly bear recovery efforts in the SBGBE has been a poster that was distributed in 1984 to increase accuracy of reports on the Clearwater National Forest (fig. 2). The poster depicts key characteristics for identifying grizzlies and gray wolves (Canis lupus irremotus) and requests that observations be reported to authorities. Informational programs to describe grizzly bear recovery efforts and ways to avoid potential human-bear conflicts will become a key factor in the SBGBE.



Figure 2.--Posters used to increase accuracy in identification of grizzlies and gray wolves.

CONCLUSIONS AND RECOMMENDATIONS

The information presented in this report suggests that a large area of land in central Idaho was once occupied by grizzly bears. A combination of factors has probably been responsible for the virtual elimination of the bear from this area, most of which have significantly changed, leaving this area of potential habitat available but virtually unoccupied. The available habitat is much larger than that suggested in the Grizzly Bear Recovery Plan. Compared to the five other identified ecosystems, central Idaho may offer the largest contiguous area of land in which to recover a viable population of grizzlies without escalating major conflicts. Further studies are clearly needed to better evaluate the situation. An adequate analysis will also require a significant increase in priority and funding for the SBGBE. Circumstantial evidence provided by 88 reports evaluated by Melquist (1985) suggests that an area of land along the Idaho-Montana border within the Clearwater National Forest would serve as potential habitat or at least a travel corridor linking the SBGBE with the Cabinet-Yaak ecosystem.

The legal mandate to recover the grizzly bear is clearly established; however, the role of each ecosystem in achieving this goal is not clear. We suggest that central Idaho may be crucial to the recovery effort; unfortunately the area is receiving little attention.

RECOMMENDATIONS

We make the following management recommendations for the SBGBE:

1. Continue to gather, evaluate, and document all potential grizzly bear reports.

2. Increase public awareness and information about grizzly bear recovery efforts.

3. Develop a plan to evaluate habitat use and movements of grizzlies known to be in the SBGBE.

4. Adequately evaluate and map grizzly bear habitat components.

5. Based on the above information, define and delineate a recovery area in central Idaho.

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USE-AVAILABILITY ANALYSIS AND TIMBER SELECTION BY GRIZZLY BEARS

B. N. McLellan

ABSTRACT: Use-availability analysis methods used to determine habitat selection will rarely find common habitats selected for even if they are often used by an individual or population. Several of these methods are briefly reviewed and a shortcoming, common to all, is identified. This shortcoming is the animal's "knowledge." It is postulated that if (1) an individual knows the location of habitats within its home range, (2) there is relatively little cost in moving between habitats, and (3) resources in a habitat are not depleted with the study's duration, then what the animal uses is what it selects. Based on this concept, the degree at which grizzly bears select the habitat component "timber" greatly increases when compared to conventional analyses. It is recommended that land management agencies recognize the potential importance of the timber component when mapping and managing grizzly bear habitat.

INTRODUCTION

The number of methodology papers written on a topic may be a function of its importance and the difficulties encountered when attempting to provide a quantitative analysis of it. Resource selection is both important and difficult to quantify. As expected, the literature describes many different methodologies. In this paper, I will briefly review some of the methods as they relate to grizzly bear habitat component (GBHC) selection and will focus on the GBHC "timber" for two reasons: First, because it is a common component in most study areas; it highlights the problem with many proposed methods of measuring resource selection. Second, in some areas the timber component is not being mapped as grizzly bear habitat.

PROBLEMS WITH EVALUATING RESOURCE SELECTION

One would think that, if a particular resource or habitat was frequently used by an individual or a population, it would be classified as "selected for." Unfortunately, the use-availability analyses used by many ecologists may find a highly used resource "used less than expected" or even "avoided." If this conclusion was uncommon, it would cause less concern; however, it is a conclusion whenever one resource is deemed by the researcher to be much more available to the animal than others.

The methods based on the forage ratio concept, although usually used for food selection, have this problem. In its simplest form, the forage ratio or preference index is the proportion of a particular resource (u) that is used, divided by the proportion that is found in the animal's environment (a) (Hess and Rainwater 1939; Hess and Swartz 1940; Williams and Marshall 1938):

$$PI = \frac{u}{a} \qquad (1)$$

If a resource is to be classified as selected for (PI > 1.0) and its proportion in the environment is large, say 50 percent, then 'u', the proportion of the resource in the use category, must be greater than 50 percent. Some authors have categorized these preference indexes or ratios as high (>1.5), medium (0.75 to 1.5), or low (<0.75) (Ault and Stormer 1983; Healy 1971). With these categories, a resource could not be classified as high preference even if it was the only resource used (u = 100 percent), unless 'a' was less than 66.7 percent. On the other hand, a resource that was rare in the environment, say 'a' = 3 percent, would have a high PI if 'u' = 5 percent.

People interested largely in a predator's prey selection have created more elegant modifications to this theme. Ivlev's "electivity index" (Ivlev 1961) was one of the first. This index is calculated with equation 2, wherein 'u' and 'a' are defined as in equation 1.

$$E = \frac{u - a}{u + a} \qquad (2)$$

Again, if 'a' is large, 'u' must also be large if the resource is not to become selected against. Jacobs (1974) recognized the problem with different abundances and modified the preference index and the index of electivity to:

$$PI = \frac{u(1-a)}{a(1-u)} \qquad (3)$$

$$E = \frac{u-a}{u+a-2ua} \qquad (4)$$

The problem with unequal availabilities, however, still occurs.

Chesson (1978) suggests a prey selection index that calculates the proportion of the diet that would consist of a particular food type if all foods were equally abundant in the environment.

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Her method likely provides a realistic estimate of prey selection in some cases, but problems arise if the index is used for habitat selection in areas of unequal habitat component availability.

The statistical method of determining resource selection as proposed by Neu and others (1974) has been commonly used to determine habitat selection by grizzly bears (Servheen 1983; Zager 1980). This method rarely finds a common resource selected for because the resource must not only be used more than its availability but significantly more. Thus, a habitat component that covers half an animal's home range (a = 0.5) may have to be used over 75 percent of the time to be classified as selected for.

The method proposed by Johnson (1980) is based on the difference between ranks of use and availability. Again, if one resource is most common (availability rank = 1) and is also most often utilized (use rank = 1), it may not be classified as highly preferred because its preference ratings will depend on the rank differences of all other resources.

The basic underlying assumption involved with statistical and index methods, which is likely true in most cases, is that in the absence of active selection, habitats or foods would be used in proportion to their availability (Chesson 1978; Pietz and Tester 1982; Talent and others 1982). If the two frequency distributions--one for resource use and the other for what the researcher calls available--differ, resource selection is indicated. Once it is agreed that animals actively "select" resources from a wide array of opportunities, we should think of how the animal does this selecting.

First, if selection occurs, an animal must be able to detect the difference between resources and determine which provide benefits and which do not. Second, to select efficiently, an animal must not only be capable of learning which resources are beneficial but also where to find them within its home range. It is believed that a major reason for an animal's establishing a home range is that it can exploit a familiar area much more efficiently than it can an unfamiliar area. How well an individual animal learns and remembers its range, choice feeding sites, bedding sites, travel routes, favored areas of potential mate, and so on, remains unknown for most, if not all, species. Some learning ability by mammal species is certain, however, and a substantial ability by some species--at least in individuals living in a predictable environment--is expected.

This assumption is based in part upon personal experience gained from radio-tracking grizzly bears. This experience leads me to believe that an animal capable of knowing its range likely moves from a known, selected feeding or bedding site over selected travel routes to other known selected sites. If this is the case, the animal will always be at a site that it has selected at that particular time for a particular reason. Therefore, the relative resource-use distribution, which a researcher obtains from sampling an animal's locations, is the same as resource selection. This applies when (1) the animal knows the location of all resources (that is, habitat components); (2) the energy costs of moving between resources are minimal; (3) the resource is not depleted during the study period, thus forcing the animal to use "second best."

An analogy may support my reasoning. Suppose a person attends a social gathering where a 500-kg steer and a 100-kg pig are being roasted on a spit. He takes a slice of beef and a slice of pork of equal proportions. Using the use-availability analysis he would have selected pork over beef when in reality he selected them equally.

I believe, for the most part, that these assumptions hold true for grizzly bears selecting at the habitat component level if they have an established home range. The selection of foods is a different matter because it is unlikely that omniscience prevails at this level of selection, although within a feeding site or a "sensing radius" the assumptions may prevail. A need for studying resource selection at each level, as mentioned by Johnson (1980), is required.

SELECTION OF TIMBER

If we agree that at the habitat component level of selection, use is equal to selection, then the apparent selection for the component "timber" changes. Servheen (1983) stratified his study area into 19 habitat components. From his figure 4, it appears that timber constituted about 15 percent of his study area and timber shrubfield about 27 percent. Using the method of Neu and others (1974), he found both of these components to be used less than expected; however, they were the fourth and second most often used of the 19 components (10 and 20 percent of locations). Why were the bears so often found in these areas if they were not preferred? They had many options.

Zager (1980) found bears avoided timber in spring and summer-fall. His figure 11 shows timber to be the fifth most commonly used of his 11 components in both seasons, with about 10 percent of the locations occurring in timber during each season. It appears that timber is used much less in the South Fork of the Flathead than in the Mission Mountains.

In my study area, the North Fork of the Flathead, grizzly bears appear to have at least four recognizable seasons, excluding winter. The first season, early spring, is from den emergence until the vegetation begins to green. This season can be about 5 weeks long for some bears but nonexistent for others. The second season, spring, is from green-up to when berries become ripe and is about 9 weeks. The third season, summer, is when berries are ripe and available. This season is usually about 8 weeks. The last season, autumn, is from when the huckleberries have largely dropped until the bears den. This season also varies in length between individuals and years but is about 5 weeks long.

Table 1.--Seasonal use of the component timber

Season	Number of bears	Bear seasons	Radio locations	Percent in timber[1]	Rank of timber
Early spring	8	16	154	41.4	1
Spring	26	50	1,471	19.9	2
Summer	22	44	1,110	8.6	5
Autumn	21	42	614	38.2	1

[1]Mean across individual bears.

Table 1 compares the use of timber during each season by the 26 bears for which adequate information was obtained. Timber was the most frequently used habitat component during early spring and autumn and second most commonly used during spring (riparian was first, and this component is often timbered as well). Only during the summer (berry season) was timber rarely used.

Determining selection of bedding and feeding sites within a component is difficult and time consuming. Consequently, only the most highly used components during the longest seasons have been investigated. The very broad and heterogeneous nature of the timber component makes estimating the selection process within it difficult. I will, however, mention some important features of this component.

During early spring, timber is the most commonly used component. Both major early spring foods, sweet vetch roots (Hedysarum sulphurescens) and large mammals, occur in this component. Unfortunately, the patchy distribution of sweet vetch within timber and many other components creates an enormous mapping problem. Grizzly bear killing and carrion-feeding sites most often occur in timber because of the concentration of winter-weakened ungulates. Timber is often used for travel and bedding during early spring. During the earliest part of this season (first 3 weeks of April), bears have been tracked through timber on the snow for many kilometers, and feeding and defecating appears to be rare.

When green-up begins (usually in mid-May), the use of timber is reduced. Foraging on grasses and other plants in wet seeps occurs in timber, as does a small amount of digging for sweet vetch. During this season timber is also used for travel and bedding. In the summer berry season, timber is rarely used.

During the autumn, timber is once again the most commonly used component. As in early spring, sweet vetch roots and ungulates--largely hunter kills, gut piles, and cripple loss--are the major foods. Fruits of several shrubs are also important. Again, it would be difficult to map only highly used timbered sites without detailed telemetry work.

SUMMARY AND RECOMMENDATIONS

Johnson (1980) mentions an imaginary situation where an animal is foraging in a site containing 90 percent of a particular food item, yet only 50 percent of its food consumption consists of that item. Conventional use-availability analysis would find that food avoided, when in reality, the animal may have chosen that feeding site because the food item was so abundant. At a higher level of resource selection, a grizzly bear may not use timber in proportion to its availability within its home range but may have chosen the home range (or be still alive in the home range) because of the abundance of timber.

How important is timber? With grizzly bears it is difficult enough to determine habitat selection. Determining habitat importance or need would require large-scale experimentation and population monitoring.

At this time I recommend that land use agencies that do not map timber as grizzly bear habitat at least mention its importance, particularly when it is adjacent to other selected habitats.

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GRIZZLY BEAR HABITAT SELECTION AND MOVEMENTS IN THE CABINET MOUNTAINS OF MONTANA

Wayne F. Kasworm

ABSTRACT: The Cabinet-Yaak Grizzly Bear Ecosystem (CYGBE) occupies about 4,860 km^2 in northwestern Montana and northern Idaho. Of this area, 90 percent is administered by the USDA Forest Service. Primary resource development demands in the CYGBE consist of mineral exploration and extraction, timber harvest, and recreation. The Cabinet Mountains Grizzly Bear Study began in 1983 through funding provided by the U.S. Borax and Chemical Corporation, the U.S. Fish and Wildlife Service, and the Montana Department of Fish, Wildlife, and Parks. Two grizzly bears have been instrumented and monitored. Telemetry from these two animals is the main source of grizzly bear habitat use data in the CYGBE. Comparisons of study results in the CYGBE are made, including management recommendations.

This information is available in:

Montana Department of Fish, Wildlife, and Parks. Cabinet Mountains grizzly bear study. 1984 annual progress report. Libby, MT; 1984.

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GRIZZLY BEAR HABITAT COMPONENTS OF THE ROCKY MOUNTAIN EAST FRONT

Keith Aune and Tom Stivers

ABSTRACT: Seventeen grizzly bear habitat components are defined for the Rocky Mountain East Front. Each is characterized by unique vegetation cover types and physical attributes. Some of these components are often closely associated with each other and are defined as component associations. Vegetation structure and composition was determined from data collected at bear activity sites. Activities of bears within each component are described. Season of use and a procedure for determining important values for each component are discussed.

This information is available in:

Aune, K; Stivers, T.; Madel, M. Rocky Mountain Front grizzly bear monitoring and investigations. Helena MT: Montana Department of Fish, Wildlife, and Parks; 1984. 239 p.

Aune, K. Rocky Mountain Front grizzly bear monitoring and investigation. Helena, MT: Montana Department of Fish, Wildlife, and Parks; 1985. 138 p.

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Session V—Habitat Improvement and Coordination

Chaired by:

Dan Hinckley, Wildlife Management Biologist, Bureau of Land Management, Billings, MT

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MANAGEMENT OF WHITEBARK PINE AS POTENTIAL GRIZZLY BEAR HABITAT

Douglas E. Eggers

ABSTRACT: Whitebark pine (Pinus albicaulis) is becoming a focal point in forest management because of its potential role in the recovery of grizzly bears. To make well-informed decisions concerning land use choices on lands which now support stands of whitebark pine, it is necessary to understand some of the species characteristics. The most important aspect of stand perpetuation is regeneration capacity. Natural regeneration has been found to be sporadic, at best, with consistent losses from birds and mammals. The seed that does survive predation has been shown to have low germination. The difficulty with poor germination also extends to seeds sown in nurseries; however, artificial regeneration with containerized stock appears to be the only presently practical, consistent method of regenerating whitebark pine.

INTRODUCTION

Whitebark pine (Pinus albicaulis) is found most often at higher elevations within its two major distributions in western North America. One population extends from about lat. 55° N. in western British Columbia to about lat. 36° N. in the Sierra Nevada. The eastern population also extends from about lat. 55° N. in Alberta and eastern British Columbia to about lat. 41° N. in northeastern Nevada. The eastern limit is the Wind River mountains in northwestern Wyoming.

The principal uses for whitebark pine are ornamental, cover and food sources for various mammals and birds, watershed maintenance, and forest products such as lumber, posts, poles, and firewood. The wood from whitebark pine is classified as "soft pine," with a specific gravity just slightly less than lodgepole pine (Pinus contorta Dougl. ex Loud.). The strength properties of the wood are similar to western white pine (Pinus monticola Dougl. ex D. Don). The species is marketed along with lodgepole pine in Canada and in Rocky Mountain portions of the United States.

Craighead and others (1982) have reported that the seeds of whitebark pine are a preferred food for grizzly bears. The importance in a particular year's diet depends on the size of the seed crop; however, when ample seed is available, bears will feed on it in the spring and fall seasons.

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ECOLOGY AND STAND REGENERATION

Tree and Stand Characteristics

Whitebark pine is a five-needled pine of the subgenus Strobus. There are two distinct morphological forms. The form that many people associate with timberline vegetation grows in clumps with two or more stems. This form occurs on the Bridger-Teton National Forest in northwest Wyoming on high ridges exposed to strong winds. These trees will sometim have a flagged, krummholz appearance, with most of the stout, flexible limbs on the leeward side of the trunk. The trees are rarely over 30 feet tall The other prevalent--if less well-recognized--grow form on the Bridger-Teton occurs in mixed or pure stands. It has a single, upright, straight stem with good form-class. These trees are of the same canopy level as the associated trees (most commonl lodgepole pine) and of similar quality. A number of pure to nearly pure whitebark pine stands on th Bridger-Teton National Forest average 75 to 90 fee tall and 12 to 14 inches d.b.h.

The bark of whitebark pine is relatively thin (rar over 1/2 inch thick), so its yield of wood for a given diameter is comparable to that of associated species. This characteristic also makes it vulner able to damage by fire.

Whitebark pine needles are medium to dark green wi a light-colored stomatal line on the back surfaces The stout, orange branchlets retain the 1-1/2 to 2-1/2 inch-long needles for as long as 7 or 8 yea before shedding them.

Whitebark pine is highly intolerant of shade exce during early stages of development. It is somewha more shade tolerant during all stages of developme under moister conditions.

Little has been published on genetic variation in whitebark pine; however, considering the range of the species, it would be safe to assume that grow period, rate of growth, and frost tolerance vary by seed source.

Associated Vegetation

In the over 50 forest habitat types identified in the eastern Idaho-western Wyoming area, whitebark pine was found in 36. On the Bridger-Teton Natio Forest, whitebark pine occurs with lodgepole pine limber pine (Pinus flexilis James), Engelmann spr (Picea engelmanii Parry ex Engelm.), subalpine fi (Abies lasiocarpa (Hook.) Nutt.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), and aspen (Populus spp.). The single-stemmed growth form i most commonly associated with lodgepole pine. Co shrub and herbaceous associates are listed in "Fo Habitat Types of Eastern Idaho-Western Wyoming".

Environmental Factors

Soils and topography.--In many areas whitebark pine distribution appears to be influenced strongly by acidic, rather than calcareous, substrates. The other five-needled pine which grows in this area, limber pine, has an apparent affinity for soils of limestone (calcareous) origin. In areas where whitebark pine appears to be climax, the soils are relatively coarse.

Topographic position affects the soil depth and severity of growing conditions and, subsequently, tree size and form. For example, whitebark pine growing on cold, windswept, southeast to northwest exposures will be short and scrubby. More protected locations produce relatively tall, symmetrical trees.

Soil moisture requirements of whitebark pine are moderate.

Insect pests.--The most important insect pest for whitebark pine is the mountain pine beetle (Dendroctonus ponderosae, Hopkins). The factors affecting mountain pine beetle attack on whitebark pine have not been studied thoroughly, but in northwestern Wyoming most attacks occur after a build up of beetle population in lodgepole pine at lower elevations.

In an endemic situation mountain pine beetles prefer the species of tree in which larvae mature. In studies done by Amman (1982), larvae raised in whitebark pine were more successful than those reared from lodgepole pine, perhaps because whitebark pine is a better nutritional source. The host preference mechanism would thus indicate that the higher the proportion of whitebark pine in a stand, the greater the amount of tree killing. The epidemic situation, however, differs in that any acceptable host will be attacked and in some cases any conifer.

Numerous other insects do not cause widespread losses but may become important periodically. These insects include moths such as the lodgepole needleminer (Argyrotaenia tabulana), bark beetles such as Pityogenes knechtel and Pityogenes carinulatus, and various species of pine engraver (Ips spp.).

Pathogens.--

1. Dwarf Mistletoe.--Dwarf mistletoe is a parasitic flowering plant which increases mortality, decreases seed production, and reduces wood production and quality. Whitebark pine is an occasional host for lodgepole pine dwarf mistletoe (Arceuthobium americanium) and a secondary host for limber pine dwarf mistletoe (Arceuthobium cyanocarpum). The limber pine dwarf mistletoe has been identified from southern Montana to Utah and Colorado; therefore, it is reasonable to assume that it exists in northwest Wyoming also.

2. Root diseases.--The most prevalent root disease is shoestring root rot (Armillariella mellea), which is associated with physiological stress, usually drought. An example of a drought situation would be steep south-facing slopes with shallow soils. When shoestring root rot results in mortality it shows up in the spring after snowmelt. Two other important root diseases are brown cubical butt rot, caused by Polyporus schweinitzii, and spongy rot, caused by Polyporus subacida.

3. Foliage diseases.--Various needle diseases are common to all pine, but the most important are Herpotrichia nigra and Neopeccia coulteri, which are snow molds. These snow molds destroy foliage when needles remain under snow for long periods.

4. Stem diseases.--A number of stem diseases affect whitebark pine; by far the most important is white pine blister rust (Cronartium ribicola). Blister rust causes spindle-shaped cankers on branches and the main stem. The result is usually death in sapling and pole-sized trees and top-kill in mature trees. The attacks of this disease are at times severe enough to kill most of the host trees in a drainage. This disease has an alternate host, Ribes spp. Several species of Ribes occur on the Bridger-Teton in habitat types which include whitebark pine. Some evidence indicates that white pine blister rust can also use Castilleja spp. as an alternate host. This is of importance on the Bridger-Teton, where Castilleja spp. is widespread. Hoff's (1980) experiments showed that whitebark pine is highly susceptible to white pine blister rust even on trees with disease-resistant parents.

Fire.--More than any other factor, fire has shaped the forests on the Bridger-Teton. The thin bark of whitebark pine makes it even more vulnerable to damage by fire than some other species. Those whitebark pine stands located on alpine areas, such as the heads of drainages, have long regeneration periods, as evidenced by historic photos taken by Gruell (1980). Natural regeneration periods of 50 years or longer in these areas are important considerations for the perpetuation of whitebark pine.

Stand Regeneration

Flowering and Fruiting.--In pines, male and female strobili are found on the same tree. Female strobili (seed cones) are most often borne in the upper crown. Male strobili (pollen cones) occur most frequently on older branches in the lower crown. This characteristic prevents much self-fertilization. A three-year interval is required from the time the male and female strobili are initiated until the time the seed matures. Cones are sessile, that is, attached at the base, not on a stalk, and occur in clusters of two to five around the end of the branches where they are not covered by needles. Pollen is usually shed in late June and early July of the second growing season. The exact time of pollination varies with latitude, site, and elevation.

As with other pine species, fertilization does not take place until 12 to 14 months after pollination. This long period increases exposure to insects and environmental changes that can reduce cone production. After fertilization, cones and seeds mature in late August and early September. Cone maturity is indicated by a change from a dark purplish brown to a dull purple or brown. The ripening cones may have beads of oleoresin issuing from resin ducts on the rounded portion of the cone scales.

Seed Production.--The literature indicates that cone bearing can begin at 20 to 30 years and collectible crops will occur at 3 to 5 year intervals. Cone production on individual trees varies greatly, primarily because of spacing. It has been consistently shown that well-spaced trees produce more seed than those growing closely together. The effect of spacing is more pronounced in intolerent species such as whitebark pine. Spacing control can produce trees with a higher proportion of fully exposed crown, which is more likely to bear flowers (Daniel 1979). This application of density management (thinning) is most valuable in pure, open-grown whitebark pine stands. In closed-canopy mixed species stands the opportunity to increase seed production is significantly less, making selection of individual trees with full crowns more important.

Seed Dissemination.--Whitebark pine cones have been described as indehiscent (remaining closed at maturity), but personal observation on the Bridger-Teton National Forest has not shown that to be the case. My observations and others' (Hutchins and Lanner 1982; Tomback 1981) demonstrate that as the cones ripen, the cones scales separate slightly to partially expose the seed. The seed, however, is held firmly in place until the cone scales come loose from the cone.

The seeds of whitebark pine are relatively heavy (2,200 to 3,000 seeds per pound). In comparison, lodgepole pine averages about 94,000 seeds per pound. The heavy, wingless seed, coupled with the cone characteristic of holding the seed until the scales come off, make wind an insignificant factor in seed dispersal. Natural seedfall from disintegrating cones could therefore only be expected to be effective from 0 to 15 feet from the tree.

The major dispersal agents are birds and mammals. Observations show that the two most effective carriers are red squirrels and Clark's nutcrackers (Hutchin and Lanner 1982).

Seed Losses.--The pine species in this area produce seeds which are important food sources for various species of birds and mammals. Hutchins and Lanner (1982) observed the following vertebrates foraging on whitebark pine in the Squaw Basin area of the Bridger-Teton National Forest: Clark's nutcracker (Nucifraga columbiana), Steller's jay (Cyanocitta stelleri), raven (Corvus Corax), pine grosbeak (Pinicola enucleator), mountain chickadee (Parus gambeli), red-breasted nuthatch (Sitta canadensis), red squirrel (Tamiasciurus hudsonicus), and chipmunk (Eutamia spp.)

Craighead (1982), Hammond (1983), and others have documented that black and grizzly bears favor whitebark pine seeds as a food source, primarily during the fall. Bears forage for seeds by pulling on the clusters of cones (from short-growth-form trees) or, more commonly, by ingesting the contents of squirrel caches.

The degree to which birds and squirrels affect the supply of whitebark pine seed is, of course, governed by the seed crop. In a year of low cone production, almost all of the seeds may be eaten, whereas in a bumper crop year a surplus of potentially germinable seeds could be cached. Hutchins and Lanner (1982) estimated the potential effect of one animal or bird to be approximately 129,000 seeds for one Clark's nutcracker and 875,000 seeds for one red squirrel. Predation by red squirrels is probably most important because the squirrels begin harvesting cones in August before the seeds are mature. Storing seeds in caches naturally decreases the area on which pine regeneration could occur.

Seed Germination.--Whitebark pine seed tested under laboratory conditions has shown a viability range of 0 to 50 percent. The viability of seed appears to be related to the developmental stage of the embryo, that is, fully developed embryos germinate more successfully.

The recommended procedure to germinate whitebark pine seeds (U.S. Department of Agriculture 1974) is to soak the seeds in cold water for 1 to 2 days, then store (while damp) in plastic bags at 33 to 41° F (0.5 to 5.0° C) for 90 to 120 days. The resulting germination rate averages about 30 percent. In Canada, where more recent experimentation has been done, Pital and Wang (1980) recommend treating seeds with sulfuric acid and cutting the seed coat. The Canadian tests have shown that seed dormancy in whitebark pine is a major barrier to their use of the species. Pital and Wang stated that if the undeveloped or underdeveloped seeds (usually those harvested too early) could not be effectively removed from the collected seed, it would not be possible to expect more than 50 percent germination even with the acid treatment.

Germination under field conditions has not been documented. Most species in the Rocky Mountains require bare mineral soil, elimiation of competing vegetation, and protection from animal damage. Whitebark pine requires the same conditions.

MANAGEMENT IMPLICATIONS

Managers of lands serving as grizzly bear habitat have the concern for maintaining whitebark pine seeds as a food source and, when possible, increase whitebark pine seed supplies. Whitebark pine management on the Bridger-Teton National Forest is oriented primarily toward nontimber purposes. Harvest and regeneration objectives on a specific site are therefore determined more by land management choice than by site factors, stand conditions, or both. The site factors or stand conditions, however, may indicate the extent to which land management objectives can be met. The objectives of maintaining or increasing whitebark pine seed as a grizzly food source can be achieved in the following ways:

1. By maintaining or converting important stands of whitebark pine to a healthy condition.

2. By increasing the proportion of whitebark pine in stands.

3. By increasing cone production in existing stands.

4. By reestablishing whitebark pine where it has been lost, expanding the whitebark pine type, or both.

Each of these methods is discussed in terms of short-term (5 to 10 years) effects; long-term effects (longer than 10 years); and whether the situation is in wilderness (part of the Wilderness Preservation System) or nonwilderness. Short-term habitat manipulation seems most critical to develop a larger bear population, but longer-term planning is necessary to maintain these levels.

Improving or Maintaining the Health of Important Stands.

This management option requires identifying the stands that are or that have been used by bears foraging on squirrel caches. The work done by Craighead and others (1982) has helped determine important habitat components, but specific stands still must be identified. It will be difficult to maintain stands in a healthy condition on the Bridger-Teton National Forest because of (1) the age and condition of the stands; (2) the presence of epidemic populations of mountain pine beetle; and (3) the large acreage within the Wilderness Preservation System.

Wilderness Areas.--There is a potential conflict between current wilderness fire management prescriptions, which allow fire to play its natural role in the ecosystem, and maintaining stands for grizzly bear use. In the short term it may be necessary to alter fire management area prescriptions to include the protection of stands important to bears. In the longer term, fire could be used to convert decadent old stands to younger age-classes for future bear food sources. There may be long regeneration periods (40 to 50 years) if entire stands are lost to insects, or fire. The use of artificial regeneration (planting) perhaps could be approved for a threatened species; however, the cost of such an operation would be high.

Nonwilderness Areas.--In areas outside proclaimed wilderness there are more options to ensure stand perpetuation. If the stands are accessible and intermingled with those planned for timber harvest, the opportunities increase because harvest, thinning, and artificial regeneration can be used to increase the health and vigor of the stands. The inaccessible areas, or those removed from access for a long time, could be managed as those in proclaimed wilderness.

Increasing the Proportion of Whitebark Pine in Mixed Stands

This method is considered effective only in the short term in stands outside proclaimed wilderness and planned for timber harvest, although there may be limited opportunity within proclaimed wilderness. The techniques for increasing the proportion of whitebark pine in a stand are common regeneration practices that should be outlined in a silvicultural prescription. Two regeneration methods appear feasible for perpetuating the whitebark pine component of existing stands. They are:

1. Natural, through favoring advance regeneration.

2. Artificial, through bare root or containerized planting stock or direct seeding.

Natural Regeneration.--The opportunity for natural regeneration from seed fall has been described previously. Closely coordinating site preparation with a good cone crop may increase regeneration success. A large cone crop would likely be necessary to yield seed in excess of that which birds and rodents usually consume.

Protecting advanced natural regeneration might help increase the whitebark pine population. Local observations indicate that although small clumps of regeneration may occur, the generally low quality of seedlings eliminates them as a significant regeneration source. If, however, a portion of a mixed stand did contain sufficient seedlings, practices such as winter logging could be used to protect them from undue damage during skidding. This strategy would be feasible where pole or sapling stands exist, but because of the advanced age of most stands, at least on the Bridger-Teton National Forest, this approach will seldom be practical.

Artificial Regeneration.--Although four potential methods of artificial regeneration exist, only one --planting--is presently practical.

1. Seed transfer. No documented work has been done on seed transfer of whitebark pine; however, we do know that seed should not be transferred to a site with more severe environmental conditions than those where the seed was collected. It would also be prudent to be narrowly restrictive to elevation zones and geographic locations until more is known.

Cones should be collected after they have changed from purple to a dull brown. The seeds should be cut to ensure that the embryo is well developed, which will mean most collections will take place after Sept. 1. The cones are most effectively collected by felling or climbing upright trees. Short, shrubby trees could be harvested with cone hooks. If any consistent collection from standing trees is to be made, the cones would need some sort of protection from squirrel and bird predation. Although collection from squirrel caches would be the easiest method, it would yield the least predictable seed.

2. Direct seeding. Seed losses from animals and birds, coupled with unpredictable germination, make direct seeding the least desirable artificial regeneration method. Direct seeding has been successful for other species, however. If these difficulties can be overcome, this method may become feasible for whitebark pine.

3. Planting. Planting is at present the only practical method of artificial regeneration. There are basically two types of planting stock available: bareroot or containerized. The extensive local knowledge and experience in the use of bareroot seedlings that has been gained with other native species would be valuable in the planting of bareroot whitebark pine. The techniques are fully covered in the USDA Forest Service's Region 4 Reforestation Handbook. The use of containerized seedlings in this area has been limited; however, such experience with other species is extensive throughout the West.

4. Germinant. Buchanan and Develise (1978) reported a relatively new approach to artificial regeneration, that of using germinated seeds. They conducted tests with ponderosa pine and Coulter pine, which are relatively large-seeded species. The survival rate was good when they covered the seedlings with protective caps. I have had similar experience using plastic cones to protect direct-seeded seedlings. This practice could be used on germinants as well. Tinus (1984) has suggested that using germinants to get just one seedling per container for containerized seedlings is a viable technique.

Regardless of the method of artificial reforestation, adequate site preparation is essential. Bare mineral soil needs to be cleared from a spot of a minimum of 18 by 18 inches. On droughty sites, or where more shrubs exist, a larger spot will be needed. It is also important to plant as soon after snowmelt as possible to make available as much moisture as possible.

Increasing Cone Production

The technology and expertise exist to increase cone production on a long- or short-term basis and within or outside of wilderness areas. The techniques that are used in seed production areas--thinning, fertilization, and protection from insects--could be used in whitebark pine stands as well. Practically speaking, however, it would be difficult to increase seed production over large areas. On an individual stand basis, thinning could be used. The application of any technique would require a thorough examination of grizzly bear use as well as of stand conditions and characteristics. Fenley (1969) and Kendall (1983), have observed the importance of considering the conditions which favor perennial caching by red squirrels. The red squirrel, as observed by Kendall (1983), may provide a large enough concentration of whitebark pine seeds to be periodically important to grizzly bears.

Reestablishing or Expanding Whitebark Populations

The opportunities for this way of maintaining or increasing whitebark pine as a grizzly bear food source are similar to that described under the heading of Increasing the Proportion of Whitebark Pine in Mixed Stands.

In some situations it may be desirable to extend the distribution of whitebark pine or to replace stands destroyed by fire or insects in wilderness and nonwilderness areas. An example might be an area with no commercial timber value that had been frequented by bears that foraged on squirrel caches containing whitebark pine cones. These stands would probably be on exposed ridges and consist of short shrubby multistemmed trees near stands of spruce and subalpine fir. Seed could be collected from these stands with an objective of selecting trees with good production. The seeds could be sown in the nursery and outplanted at the periphery of the existing stands or in other adjacent areas that had contained whitebark pine as a component.

CONCLUSIONS AND RECOMMENDATIONS

In summary, in the short term we should use proven silvicultural techniques to maintain or increase whitebark pine seed production in existing stands. In the long term we may be able to extend the presence of whitebark pine primarily through artificial regeneration, even though this strategy is not immediately available. The technique will become feasible if consistently high-quality seedlings can be produced.

Future research on whitebark pine should focus on the following areas:

1. Improving our knowledge and skill in nursery propagation of seedlings.

2. Defining further the silvicultural practices that will enhance cone and seed production.

3. The relationship of other tree species to the long-term maintenance of red squirrels in a vicinity to ensure whitebark pine seed is concentrated for grizzly bear use.

4. The current rate of replacement (natural regeneration) in existing stands.

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ENHANCING GRIZZLY BEAR HABITAT THROUGH TIMBER HARVESTING

Mike Hillis

ABSTRACT: On the Lolo National Forest in western Montana, drainage forbfields and other very moist habitat components are given special management emphasis because of their relative scarcity and sensitivity to management. Desired grizzly bear foods commonly found in drainage forbfields have been observed on certain microsites within clearcuts. Closer examination revealed that broadcast-burned clearcuts in poorly drained subalpine fir/clintonia or subalpine fir/bluejoint habitat types produced vegetative communities similar to drainage forbfields. Based on these observations, two timber sales were initiated within essential grizzly bear habitat to test the validity of these observations. Vegetative conditions will be monitored following treatment to test the forb response. Unlike drainage forbfields, shrubfield/cutting units are a common habitat component throughout the Lolo National Forest. Producing desirable grizzly bear foods by logging Douglas-fir/blue huckleberry, grand fir/beargrass, and other habitat types is a fairly predictable process. Grizzly bear habitat management strategies in such situations should be based on avoiding human-caused mortality and scheduling timber harvest so that the area produces a sustained, even flow of grizzly bear foods within cutting units. This latter strategy can be achieved by (1) inventorying timber stand age classes in the project area; (2) sampling existing units of varying ages in the area to determine the average period in which grizzly bear foods are produced following treatment; and (3) determining the optimal long-term harvest entry interval and treatment intensity.

INTRODUCTION

Because there are no documented instances in which habitat manipulation has directly produced more grizzly bears, managers do not readily accept the idea of enhancing grizzly bear habitat with timber harvest. On the Lolo National Forest, we believe we can safely implement the concept if we avoid creating disturbances and human-caused mortality of habitat. The argument that "we don't know enough" to enhance grizzly bear habitat may not be defendable for two reasons: (1) many of the Forest's inventoried habitat components occur in seral or disturbance-related situations (Cline and others 1984; Tirmenstein (1982) and (2) our knowledge of habitat type response to certain silvicultural treatments is good (Arno and others 1985; Pfister and others 1977). Thus, if certain seral plant communities provide good grizzly bear habitat and if we can predictably create those communities without increasing the risk of mortality, then habitat enhancement is an appropriate management goal.

On the Lolo National Forest, habitat enhancement is one of our recovery strategies, secondary only to minimizing mortality. On our reasonably productive nonwilderness sites, we have two Forest Plan allocations that use timber harvest, prescrib fire, or both to enhance habitat. Although no one knows exactly how to artificially create optimal habitat for grizzly bears, we are experimenting with several types of enhancement. Two of the more promising types are treating wet microsites to create artificial drainage forbfield and a technique for scheduling timber harvest in potential shrubfield/cutting units.

WET MICROSITES

The Lolo National Forest shares a portion of the Cabinet-Yaak and north Continental Divide grizzly bear ecosystems. It is evident from 3 years of habitat component mapping that the Lolo National Forest has some of the poorer, drier parts of both ecosystems (Cline and Tirmenstein 1984). There are two reasons for this: less precipitatio and disproportionately more well-drained soils within the grizzly bear ecosystems (Sasich 1984). "Wet" habitat components, such as drainage forbfields and wet meadows, are particularly scarce on the Lolo National Forest. Because these components are important as spring and midsummer food sources, management of these components and other comparable wet components ha been given a special management priority. Manage often consider drainage forbfields to be a semipermanent "climax" vegetative feature, but Lolo National Forest personnel have observed grizzly bear foods, such as Veratrum viride (northern false-hellibore), Heraculum lanatum (common cowparsnip), and Angelica arguta (angelic which normally occur in drainage forbfields, in large concentrations within clearcuts. This finding raises two questions: (1) Why does that positive vegetative response occur? and (2) Is it possible to deliberately create those vegetative communities? The first logical step in answering these questions was to sample those clearcuts to see what kind of common characteristics they shar

After 3 years of vegetative sampling, it appears that there are indeed some common characteristics

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in these sites. Typically, a clearcut that had a "drainage forbfield" in the middle had these characteristics:

1. The clearcut was very large and included several different habitat types,

2. Geographic features, including swales, slumps, and areas immediately behind small terminal moraines, were significantly more poorly drained than in the surrounding area.

3. Habitat types within these poorly drained microsites were often, but not always, subalpine fir/clintonia-clintonia (ABLA/CLUN-CLUN), subalpine fir/bluejoint-bluejoint (ABLA/CACA-CACA), or subalpine fir/bluejoint-bedstraw (ABLA/CACA-GATR).

4. The wet microsite was heavily scarified. In all cases, the clearcut had a high fuel load and was broadcast burned.

5. Although the wet microsite had enough stumps to indicate that the site was at one time fully stocked, the water table had risen following harvest to the extent that conifer regeneration was nonexistent for up to 25 years.

The relationship among these characteristics was not evaluated statistically; however, few exceptions were found. In looking at these common characteristics, it appears possible to create drainage forbfields by harvesting timber from midelevation timber communities where ABLA/CLUN or ABLA/CACA habitat types are found. It is fairly common in certain land types on the Lolo National Forest to encounter pockets of poorly drained soils. It thus appears that when these sites are forested, tree removal, accompanied by scarification, could produce productive forb communities.

In designing a timber sale program to create such microsites, however, several problems have been encountered. For instance, where the wet site is very small (less than 1 acre) habitat type indicators may be difficult to find. In such cases, conifers may be tying up the available moisture to the extent that vegetative indicators, such as clintonia, are almost nonexistent (Sasich 1984). In such cases, topographic features such as slumps or swales may be the only indication of available subsurface moisture. Another problem we have noted is that there is considerable variability in how given habitat types, particularly ABLA/CLUN (all phases), respond. For instance, ABLA/CLUN-CLUN at the drier extreme produces many shrubs, including Sorbus sitchensis (sitka mountainash) and Cornus occidentalis (western dogwood). Although these plants are excellent grizzly bear foods, the more plentiful of the two, dogwood, occurs under a canopy; hence timber harvest in this moisture regime may not be beneficial. Forb-dominated conditions seem to occur only at the wet end of ABLA/CLUN-CLUN, where the site is too wet for shrubs. Even at the wet end, however, Alnus sitchensis (alder) may dominate the community after treatment if present in the pretreatment understory and may inhibit the forb response. Getting a forb-dominated community after treatment may still be possible in such situations if the site can be scarified. Losensky (1983) has noted that in very wet sites tractor-piling of slash will temporarily eliminate alder and thus allow the site to be occupied by forbs and grasses. Unfortunately, this poses another problem because it is not always possible to burn or mechanically scarify wet areas. One possible solution is to mechanically scarify the site immediately after logging, before the water table has risen appreciably. Also, the technological jump in burning difficult moist habitat types during the summer may help to solve the problem.

Lolo National Forest has initiated a timber harvest program in essential habitat on a variety of sites to test forb response potential. The program is designed to take into account the problems previously described. Treatment areas have been selected based on the following criteria: (1) bear units in the area have an inherent scarcity of drainage forbfield or other "wet" components; (2) land types have a high potential for having wet microsites in ABLA/CLUN or ABLA/CACA habitat types; (3) merchantable and marketable stands are present; and (4) disturbance and an increased risk of human-caused bear mortality can be avoided.

Two sales were identified that could meet these criteria if their boundaries were extended. Wet sites were identified that could produce forb or sedge communities if treated. Several 2- to 4-acre clearcuts were designated for treatment within this area. These treatment opportunities were incorporated into project Environmental Analyses (EA's). One EA has been approved, and one EA is pending. A number of constraints in the project plans are designed to avoid disturbance and mortality. These included seasonal operating constraints (no activity during periods of probable bear use) and stringent requirements on postsale road management. Pretreatment and posttreatment monitoring on the "forb units" will include an inventory of all plants on the sites by species and crown density. Posttreatment monitoring will be done for 5 years. Scarification levels will also be measured on those sites that were scarified. Forb response will be compared with the pretreatment vegetative data so that the results can be determined.

DISCUSSION

It will be several years before we have any conclusive results on forb response. Based on past observations, I think the question is not whether the sites respond favorably, but to what degree and whether the response is worth the effort. One interesting option of the project will be to look at long-term tree regeneration surveys to see if increased water tables can successfully delay regeneration. Based on observations, it appears likely that we will not get any appreciable regeneration for 30 to 40 years. If so, this will make the treatments more cost effective since the benefits will be fairly long term. The essential criterion for any treatment is, however, will it benefit the bear? Assuming that (1) mortality risks are not

increased (and in both projects we have taken significant measures to ensure that does not happen); (2) disturbance is avoided; and (3) a scarce food supply is increased within a bear unit, the least we can say is "it can't hurt." I think logically such treatments may in the long run contribute to recovery.

SHRUBFIELD/CUTTING UNITS

Many of the well-drained midelevation sites on the Lolo can be classified as shrubfield/cutting units components if regenerated and scarified (either with burning or mechanical piling). Habitat types that respond especially well (from the berry-producing shrub standpoint) include Douglas-fir/blue huckleberry (PSME/VAGL), subalpine fir/beargrass/blue huckleberry (ABLA/XETE/VAGL), and grand fir/beargrass (ABGR/XETE) (Arno and others 1985; Pfister and others 1977). Thus, it is a simple matter to produce berry-producing shrub communities, most of which provide some type of bear food, if we clearcut (or seed-tree cut) and broadcast burn such areas. Some of the typical shrubs that will be abundant after treatment include Sambucus spp. (elderberry), Sorbus sitchensis (sitka mountainash), Amelanchier alnifolia (Saskatoon serviceberry), and Sheperdia Canadensis (russet buffaloberry). I have excluded Vaccinium spp. (huckleberry) because it responds better if stands are partially cut and not burned (Minore and others 1979; Miller 1977), which makes it somewhat different than the other shrubs. By harvesting timber in these types and taking precautions to avoid grizzly bear disturbances and mortality, it is easy for land managers to delude themselves into thinking that they are doing everything possible for the bear. Unfortunately, unless managers are willing to provide a continual flow of this food source over time, treatment may not be beneficial.

The following example shows how opportunities for habitat enhancement can be forgone when managing this vegetative type. The "shrub life" in regeneration units, or the period in which berry-producing shrubs are a major vegetative component after logging, varies. Let us assume that clearcuts within a given bear unit have an average shrub life of 30 years. If the timber age classes were predominantly old growth, and we liquidated those stands in 40 years (assuming we could at the same time retain adequate amounts of cover and security), we would exhaust our transitional berry-producing options in 70 years (40 + 30). Faced with a 110-year rotation, we would have 40 years of relatively sterile pole stands and no shrubfield components.

The way around this problem is to schedule timber harvest to optimize this food source over time. Although the solution may appear obvious, it is one that is often overlooked when we are faced with the immediate need to minimize disturbance and mortality. On the Lolo National Forest, we have developed a simple model that involves (1) inventorying all timber stands that have shrubfield potential by age class; (2) sampling cutover stands to determine "shrub life"; and (3) developing, using age class histograms, an optimal harvest schedule that produces an even flow of shrubfield cutting units. The product of this model is a harvest strategy that identifies the number of entries needed over time, the average acres harvested per entry, and the optimal interval between entries.

On a 10,000-acre project area where the system was practiced, the model has worked like this:

1. Timber age class data, collected by Timber Stand Inventory crews, and secondarily in non-inventoried stands by photo interpretative maps, were categorized by successional stage (fig. 1).

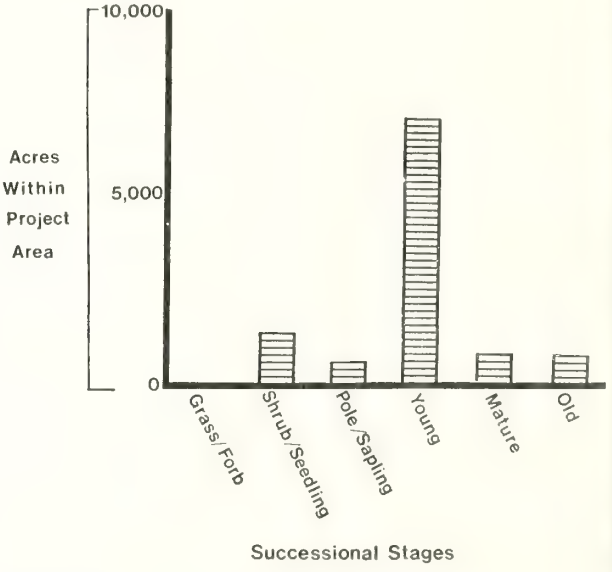


Figure 1.--Timber age-class distribution by successional stage within a sample project area.

2. Existing clearcuts in the area were sampled for berry-producing shrubs. A subjective rating was given for individual shrubs based on their relative level of vigor. Clearcuts harvested in the 1970's showed significantly higher levels of shrub vigor than units harvested in the earlier 1960's, although the latter were still producing berries at higher levels than uncut stands. Based on this analysis, it was assumed that units in the area had an approximate "shrub life" of 30 years.

3. If the 30-year shrub life is compared with the current age class distribution (fig. 1), it becomes evident that timber harvest will be necessary to retain the shrub community. In other words, as the 20-year-old clearcuts mature and no longer produce berries, no grass/forb communities are available to replace this food source. A number of different harvest intensitie and entry intervals were tested by developing histograms to see which harvest option would produce the most sustainable levels of shrubfield cutting unit components over time. Additional criteria, including optimal marketable sale size, were imposed to ensure that the optimal

strategy for producing grizzly bear foods was compatible with timber industry marketing needs. From the bear food standpoint, the most effective harvest program is one that (1) clearcuts 900 acres (in 10 30-acre units) every 20 years from a 70- to 90-year-old larch and lodgepole component; (2) defers treatment from 400 acres of old growth because the area is associated with some riparian cover corridors; and (3) defers treatment, for 60 years, in 700 acres of commercially thinned 70-year-old larch because of status as a desirable timbered vaccinium habitat component. If the last scheduled entry is made in 60 years, this program would provide bear food for 90 years, at which time existing clearcuts would be ready for the next treatment. Figure 2 shows various age classes available by time period; the critical elements are maintaining the shrub/seedling age class and maintaining older age classes that can be clearcut to create rich shrub/seedling communities.

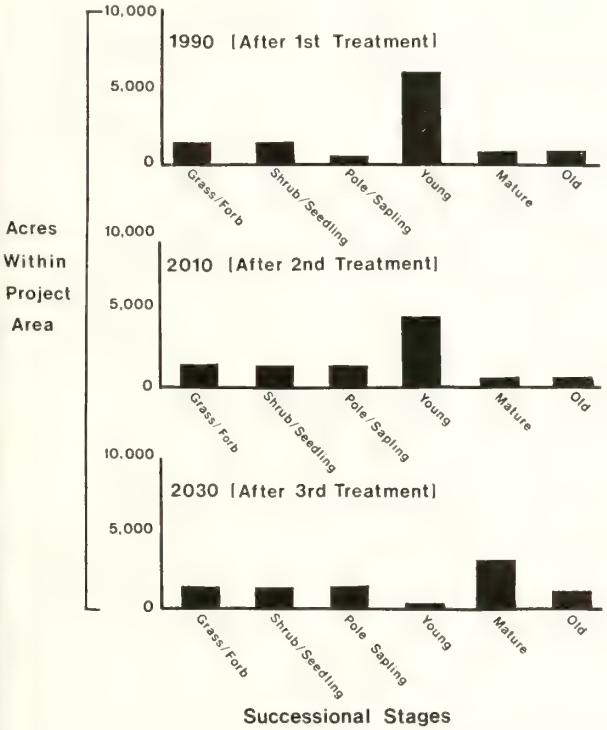


Figure 2.--Tree age-class distribution through the year 2030 that is achieved by harvesting 900 acres of timber from the young age class every 20 years. Note the perpetuation of shrub/seedling communities which produce shrubfield/cutting unit habitat components.

DISCUSSION

This method appears simplistic, because in practice many other factors, including the avoidance of timber age classes susceptible to mountain pine beetle outbreaks and the protection of other grizzly bear habitat components also affect project design. Even so, it should be evident that in situations where a majority of bear foods are "transitional" and are stimulated through timber harvest, the capacity to sustain these transitional foods should be considered in long-term harvest planning. Long-term monitoring will test the final appropriateness of this strategy.

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GRIZZLY BEAR HABITAT COMPONENTS ASSOCIATED WITH PAST LOGGING PRACTICES ON THE LIBBY RANGER DISTRICT, KOOTENAI NATIONAL FOREST

Alan A. Bratkovich

ABSTRACT: Seventy cutting units harvested from 1950 to 1980 and ranging in size from 5 to 200 acres were evaluated for the occurrence of bear foods. Units were treated with various silvicultural and site preparation methods and occurred in various habitat types on grizzly bear spring, summer, and fall range. Timber harvest occurred on both Forest Service and private land with no documented intent of benefiting grizzly habitat at the time of harvest. Habitat component mapping and data from 1/10 acre vegetative plots suggest that certain conditions enhanced bear food production. Grizzly habitat components, including riparian stream bottom, wet meadow, dry meadow, and mixed shrubfield cutting units, resulted from timber harvest. Observations indicate that timber harvest and site preparation methods on certain sites can enhance bear food production.

INTRODUCTION

The east side of the Cabinet Mountains is characterized by glaciated U-shaped drainages that drain east into the Libby Creek valley bottom (fig. 1). Approximately 100,000 acres are mapped as grizzly bear habitat, management situation 1 (Kootenai National Forest 1985). Use of the area by black bears (Ursus americanus) and grizzly bears (Ursus arctos horribilis) is documented throughout.

Most timber harvest activities on National Forest land along the east slope of the Cabinets began in 1960; about 70 million board feet of timber were harvested on approximately 100 cutting units during the sixties and seventies. The predominant silvicultural treatment was clearcutting, with precommercial and commercial thinning occurring to a lesser degree along with overstory removal and group selection cuts. Site preparation methods include dozer piling with machine scarification and broadcast burning. The sites of some thinning units and overstory removals and group selection cuts were not treated. Except for a few parcels of private land and several patented mining claims, the area is part of the Kootenai National Forest administered by the Libby Ranger District.

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To better coordinate unit layout and harvest and site preparation methods for the purpose of enhancing bear foods, we attempted to determine if, or to what extent, past timber harvest activity increased bear food production on various sites in grizzly habitat. We gathered information on the composition and ground coverage of recognized bear foods in the cutting units and the adjacent untreated areas in order to compare the quantity and quality of bear foods in treated and untreated areas.

Data and observations compiled to date indicate that some timber harvesting appeared to positively influence bear food production; some cutting units were subsequently mapped as grizzly habitat components. Habitat components and mapping procedures are taken from Madel (1982) and have subsequently been adopted by the U.S. Department of Agriculture, Forest Service, Northern Region.

METHODS

Habitat component mapping precedures substantiated with 1/10-acre vegetative plots (Madel 1982) were used to evaluate past logging units and untreated mature coniferous stands. The objective was to evaluate and compare bear food production in logged units and in adjacent untreated conifer stands with similar site parameters, including habitat type, slope, aspect, and elevation. Information on cutting unit history, including harvest date and type, site preparation date and type and habitat type, was recorded for units located in grizzly bear habitat along the east Cabinet Mountain face. This information was taken from the Libby Ranger District Timber Stand Improvement Data Base and then field-checked for verification. Forest habitat types from Pfister (1977) were also recorded for a more complete description of site potential and productivity. Madel (1982) provides a complete species list of bear foods by habitat components for the Cabinet Mountains.

Sampling of cutting units and adjacent untreated areas in delineated grizzly habitat began at Granite Creek and systematically proceeded south to West Fisher Creek (fig. 1). Units felt to be representative of the site were stratified and sampled regardless of ownership. One-tenth-acre circular plots with a radius of 35.8 ft. were located inside cutting units in areas felt to be representative of the ground vegetation in the unit. The same criteria were used for sampling the ground vegetation in the adjacent conifer stands. A complete species list including percent canopy coverage, along with vegetation structure,

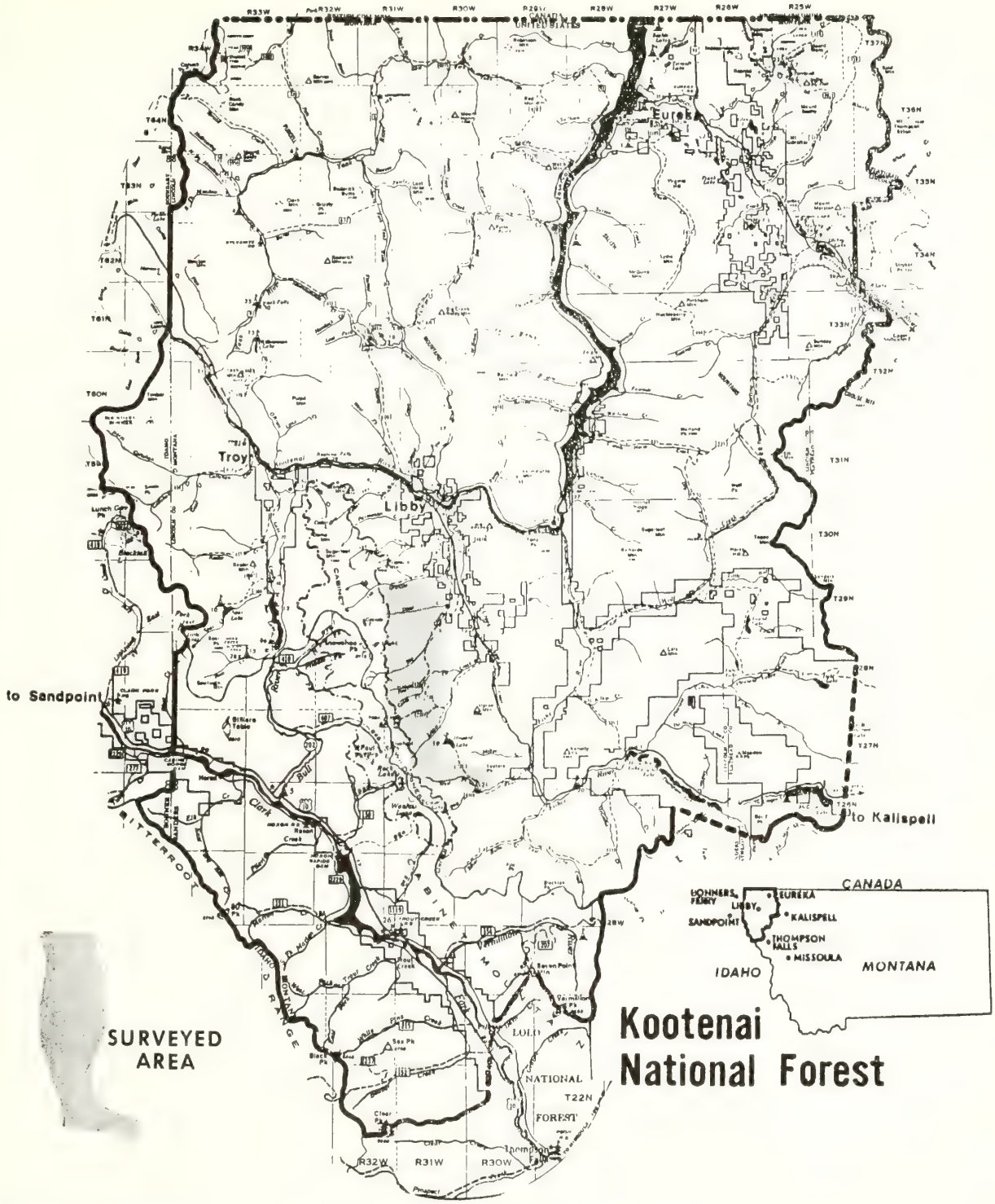


Figure 1.--Surveyed area along the east front of the Cabinet Mountains.

elevation, aspect, slope, and canopy closure as determined by spherical densiometer readings, was recorded for each site. Madel (1982) provides a complete precedural description.

A coverage class of 3, indicating that 25 to 50 percent of the ground surface area of the plot was covered by a particular bear food plant species, generally was considered a desirable forage condition. This determination was made after analyzing coverage classes of bear foods within like, naturally occurring components in the Cabinet Mountains. Bear foods in the next lower coverage class of 2 (5 to 25 percent) generally were not considered sufficient to be classified as a foraging site. This category had to be viewed cautiously, however, because the presence of several bear food plant species within a given plot, each approaching 25 percent coverage, sometimes warranted classification as a desirable foraging condition.

Forty-five units were sampled with vegetative plots, and 25 units were sampled by a walk-through transect without taking plots. The walk-through transect differed from vegetative plots only in that observers visually estimated representative sites without recording coverage classes of bear foods. Observers then subjectively evaluated the value of the unit or site as a foraging component. This was done to expedite sampling only when an experienced evaluator had sampled enough to make accurate estimations.

The number of plots per unit varied in relation to size of unit and uniformity of ground vegetation. Areas with fairly consistent bear food plant species or units of small size were not sampled as intensively as very large units or units where the occurrence of bear foods was discontinuous.

In total, 70 units were evaluated for the occurrence of bear foods, along with 80 sites in adjacent uncut stands. Sites on either side of a cutting unit were occasionally sampled for a more accurate representation, thus accounting for the greater number of sites in uncut stands. Statistical analysis was not used to evaluate or compare data.

RESULTS AND DISCUSSION

Of the 70 cutting units evaluated, 30 had sufficient bear foods to subsequently be mapped as grizzly habitat components (table 1). The main criterion used to determine whether a site supplied adequate foraging value was the occurrence of at least two bear foods at a coverage class of 3 (25 to 50 percent) each as analyzed from the vegetative plots. Another criterion was the dominance of one bear food with a plot coverage of over 40 percent and its subsequent classification within a coverage class of 3 or 4 (50 to 75 percent). Graminoids in the wet meadow or sidehill park component more typically met this criterion. Consideration was also given when three or more bear foods occurred at a coverage class of 2 (5 to 25 percent) with coverages at the upper end of the spectrum close to 25 percent. Madel (1982) discusses the use of other general criteria.

Table 1.--Data from 30 units producing sufficient bear foods to be mapped as habitat components

Resulting habitat component[1]	Cutting unit	Topographic location			Harvest type[2]	Year	Site preparation[3]	Habitat type[4]	Area
		Elev.	Aspect	Slope					
		Ft	Degrees	Percent					Acres
Riparian stream bottom	E11	3,000	-	0	CC	1979	DP/MS	TSHE/CLUN	5
Riparian stream bottom	E12	3,080	-	0	CC	1979	DP/MS	TSHE/CLUN	3
Riparian stream bottom	E22	3,500	90	25	CC	1969	BB	TSHE/CLUN	32
Riparian stream bottom	C500	4,000	-	0	CC	1962	None	ABLA/CLUN	65
Riparian stream bottom	B10	4,000	-	0	CC	1973	DP/MS	TSHE/CLUN	15
Wet meadow	C666	3,600	-	0	CC	1951	BB	TSHE/CLUN	50
Dry meadow	E9	3,500	135	25	CC	1979	DP/MS	TSHE/CLUN	32
Dry meadow	E28	3,200	90	5	CC	1980	DP/MS	TSHE/CLUN	10
Dry meadow	C140	3,400	-	0	CC	1970	BB	TSHE/CLUN	89
Dry meadow	C127	4,000	90	10	CC	1968	DP/MS	TSHE/CLUN	107
Dry meadow	C126	3,700	-	0	CC	1968	BB	TSHE/CLUN	38
Mixed shrubfield	E4	3,700	90	20	CC	1966	BB	TSHE/CLUN	24
Mixed shrubfield	E5	3,400	90	15	CC	1966	DP/MS	TSHE/CLUN	80
Mixed shrubfield	E19	3,400	90	15	CC	1966	BB	TSHE/CLUN	60
Mixed shrubfield	C124	3,800	45	5	CC	1970	BB	TSHE/CLUN	106
Mixed shrubfield	B9	4,000	90	25	CC	1970	BB	TSHE/CLUN	105
Mixed shrubfield	C400	5,000	180	35	CC	1960	BB	ABLA/XETE	35
Mixed shrubfield	B20	4,300	135	10	CC	1960	DP/MS	TSHE/CLUN	10
Mixed shrubfield	B25	4,400	135	10	CC	1960	BB	TSHE/CLUN	30
Mixed shrubfield	B26	4,500	135	30	CC	1960	DP/MS	TSHE/CLUN	20
Mixed shrubfield	B15	4,300	315	20	CC	1973	BB	TSHE/CLUN	10
Mixed shrubfield	D200	4,200	180	30	PCT.	1967	None	TSHE/CLUN	50
Mixed shrubfield	D300	4,200	180	30	PCT.	1967	None	TSHE/CLUN	45
Vaccinium shrubfield	C15	3,600	45	30	CC	1969	BB	TSHE/CLUN	51
Vaccinium shrubfield	C10	4,200	45	25	CC	1969	BB	TSHE/CLUN	48
Vaccinium shrubfield	C107	4,100	90	15	CC	1969	BB	TSHE/CLUN	48
Vaccinium shrubfield	C136	4,400	45	25	CC	1971	BB	THPL/CLUN	45
Vaccinium shrubfield	C300	5,600	180	40	OSR	1960	None	ABLA/XETE	10
Timbered Vaccinium shrubfield	A20	5,000	180	35	GS	1966	SB	ABLA/XETE	20
Timbered Vaccinium shrubfield	A22	4,600	135	30	GS	1966	SB	ABLA/XETE	45

[1] From Madel (1982).

[2] CC-clearcut; OSR-overstory removal; PCT-precommercial thin; GS-group selection.

[3] DP/MS-dozer-piled/machine scarified; BB-broadcast burned; SB-spot burning.

[4] From Pfister (1977). TSHE/CLUN-western hemlock/beadlily; ABLA/CLUN-subalpine fir/beadlily; THPL/CLUN-western redcedar/beadlily; ALBA/XETE-subalpine fir/beargrass.

Components identified in the cutting units included riparian stream bottom, wet meadow, and mixed shrubfield cutting units, including huckleberry (Vaccinium globulare) shrubfields and timbered huckleberry shrubfields.

Eighty sites were sampled in adjacent timbered stands having similar site characteristics with no prior treatment (table 3). With the exception of three sites, the understory ground vegetation was depauperate of bear foods mainly due to the dense canopy closure. When succession progresses to the point where shade-tolerant trees become dominant in the canopy, shading can eliminate many species and reduce coverage of even the most persistent forbs to just a trace (Pfister 1977). The only exceptions were in three riparian zone areas where the surface water of natural seeps or braided channels increased soil moisture and appeared to positively influence desirable plant production. Natural openings in the canopy due to tree mortality or blowdown allowed increased light penetration to the forest floor and also appeared to favorably influence plant response.

Areas depauperate of bear foods along stream bottoms are likely to produce desirable spring bear foods, such as wet site forbs and graminoids, if converted to earlier successional stages by total or partial removal of the canopy. Both the riparian stream bottom and wet meadow component resulted from logging activity adjacent to stream channels (table 1). Desirable wet site forbs, ferns, and grasses included cow parsnip (Heracleum lanatum), angelica (Angelica spp.), horsetail (Equisetum spp.), fern species (Polypodiaceae), sedges (Carex spp.), and grasses (Calamagrostis canadensis). Site preparation methods, including broadcast burning and dozer piling with machine scarification, did not appear to be a factor in establishing desirable forbs and graminoids in riparian areas. Only two of the riparian units sampled did not have adequate quantities of bear foods to be mapped as components (table 2); however, these units were sampled only 2 years after site treatment, which may have been a factor in the low occurrence of bear foods. Personal observations of dozer-piled riparian clearcuts along the east Cabinets have indicated that bear foods do not become widespread until 3 or 4 years after treatment.

Harvest units in the warm and moist habitat types in the western hemlock (Tsuga heterophylla) and western redcedar (Thuja plicata) series, and also in the cool and moist habitat types in the subalpine fir (Abies lasiocarpa) series, still had sufficient quantities of bear foods to meet the criteria for a desirable foraging site 10 to 25 years after treatment.

Three hundred acres of clearcuts were dominated by a grass-sedge community and subsequently mapped as a dry meadow component (table 1). Some of the desirable grasses and forbs present included sedges (Carex spp.), bromes (Bromus spp.), orchardgrass (Dactylis glomerata), timothy (Phleum pratense), thistle (Cirsium spp.), and clovers

Table 2.--Data from 40 cutting units not producing sufficient bear foods to be mapped as habitat components

Harvest period	Total no. of units	Topographic location: Riparian (3,000-4,000 ft)	Terrace (3,000-4,000 ft)	Upland (4,001-5,000 ft)	Aspect (°): 0-90	91-180	181-270	271-360	Slope (%): 0-20	21-40	Harvest type[1]: CC	OSR	PCT	Site preparation[2]: BB	DP/MS	None
	Number of units															
1961-65	7	-	7	-	4	2	-	1	7	-	7	-	-	1	6	-
1966-70	16	-	14	2	13	3	-	-	16	-	13	3	-	5	7	4
1971-75	3	-	2	1	2	-	-	1	1	2	3	-	-	1	2	-
1976-80	14	2	10	2	9	5	-	-	9	5	13	-	1	2	8	4

[1]CC-clearcut; OSR-overstory removal; PCT-precommercial thin.

[2]DP/MS-dozer-piled/machine scarified; BB-broadcast burn.

Table 3.--Data from 80 sites sampled in mature conifer stands spatially adjacent to cutting units (only 3 sites were subsequently mapped as habitat components as determined by the quantity of bear foods)

Topographic location	No. sites sampled	Habitat type[1]: TSHE/CLUN	THPL/CLUN	THPL/OPHO	Aspect (°): 0-90	91-180	181-270	271-360	Slope (%): 0-20	21-40	>40	Canopy closure (%): 50-70	70-100
		Number of units											
Riparian 3,000-4,000 ft	34[2]	32	3	9	26	8	-	-	30	4	-	3	31
Terrace 3,000-4,000 ft	40	36	3	1	21	15	-	4	30	7	3	2	38
Upland 4,001-5,000 ft	6	5	1	-	2	4	-	-	-	4	2	-	6

[1]From Pfister (1977). TSHE/CLUN-western hemlock/beadlily; THPL/CLUN-western redcedar/beadlily; THPL/OPHO-western redcedar/devil's club.

[2]Three sites in this sample were mapped as the riparian stream bottom habitat component. One site in each of the three habitat types listed.

(Trifolium spp.). Habitat type was western hemlock/ beadlily. Both dozer piling with machine scarification and broadcast burning site preparation methods produced desired vegetative response of graminoids and sedges. Some units, currently ceanothus (Ceanothus spp.) and alder (Alnus sinuata) shrubfields, were treated before 1970 and were depauperate of bear foods (table 2). These units may have had adequate coverages of spring bear foods when in the grass-forb stage, but this could not be conclusively determined. The lack of graminoids and sedges in 15 units harvested between 1970 and 1980 could not be completely explained, although many of these units had high coverages of pinegrass (Calamagrostis rubescens) that rapidly invaded the site and may have prevented the establishment of desirable graminoids. Four of these units also had heavy slash accumulations without site treatment, making on-site establishment of bear foods unlikely.

Nineteen units responded well with fruiting shrubs such as huckleberry (Vaccinium globulare) and serviceberry (Amelanchier alnifolia), along with buffaloberry (Sheperdia candensis) and mountain ash (Sorbus scopulina) to a lesser degree. These units occurred on the subalpine fir/beargrass/ huckleberry habitat type on higher southerly aspects and also on the western hemlock/beadlily/ beadlily type on the cooler, better drained, easterly aspects (table 1). Canopy removal on these sites followed by broadcast burning or no site treatment produced the most fruiting shrubs. Components mapped in these units included mixed shrubfields, huckleberry shrubfields, and timbered huckleberry shrubfields.

Martin (1979) states that fruit production generally remains high until the tree canopy exceeds 30 percent cover. Almost 100 percent of the timbered stands located on similar sites and adjacent to the cutting units had tree canopy closure of 70 percent or greater (table 3). Clearcutting, overstory removal, group selection, and precommercial thinning were harvest methods which produced shrubfield components on these sites. The fruiting shrub response in the understory of cutting units with no site treatment appeared to be associated with increased light penetration to the forest floor due to canopy removal. Although huckleberry was present in trace amounts in the understory in many adjacent timbered stands, the shrubs appeared suppressed and unproductive.

Martin (1979) also states that competition from other shrub species can be quite limiting to huckleberry plant cover and berry production. This may account for the fact that the six clearcut units broadcast burned from 1961 to 1970 showed little or no coverage of fruiting shrubs, particularly huckleberry (table 2). These units had high coverages of evergreen ceanothus (Ceanothus veluntinus) and redstem ceanothus (C. sanguineus), which are both capable of responding prolifically to fire treatment.

Broadcast burning appeared to be the best treatmer for encouraging fruiting shrubs. It appeared that heavy scarification of units on the drier, rounded side slopes may have been a factor in preventing desired shrub response. Zager (1980) found that huckleberry plant cover and production was very low in scarified clearcuts, because scarification extensively damages rhizomes, which are the primar storage organs for carbohydrates and nutrients necessary for growth and development.

Data and observations to date indicate that silvicultural treatments on certain sites appear to positively influence bear food production. Evaluation of past cutting and site preparation methods thus enables better coordination of timber sales with seasonal bear food requirements

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GRIZZLY BEAR DIRECT HABITAT IMPROVEMENT ON THE KOOTENAI NATIONAL FOREST

Ernesto R. Garcia

ABSTRACT: Forest management practices on the Kootenai National Forest have profoundly affected the grizzly bear (Ursus arctos horribilis) and its habitat. These effects, of long and short duration, have been both positive and negative. Past efforts to accommodate grizzlies during forest management have been primarily reactive, focusing on mitigation measures such as road closures and activity scheduling restrictions. More recently, biologists have taken a more proactive approach, attempting to directly improve habitat with projects such as patch cutting accompanied by burning and/or seeding of umbels; prescribed burning; road seeding of graminoids and legumes; and planting of berry-producing shrubs. Many of these projects are as yet untested or partially completed. This paper describes these projects and the monitoring methods designed to determine their biological effectiveness.

INTRODUCTION

Within the Cabinet-Yaak Grizzly Bear Ecosystem of northwestern Montana, intensive timber management, in conjunction with other forest activities, has increased the need for adequate and effective mitigation of logging impacts. Forest biologists recognize this need and the importance of promoting the positive effects of habitat manipulation wherever possible. Additionally, projects are being conceived which might augment existing habitat values. In the following examples of such projects, basic considerations in project type and site selection included (1) the potential to produce desired vegetation response (habitat type), (2) juxtaposition of site to existing grizzly habitat components (i.e. placing the project near an area already frequented by bears), (3) ability to control human disturbance, (4) compatibility of land use objectives, and (5) available funding.

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SELECTIVE PATCH CUTTING

Diverse habitats provide a variety of plant communities, each of which may be seasonally important in meeting a bear's total annual needs. Timber harvest, due to its potential to increase habitat diversity, can thus be an effective means of accomplishing bear habitat objectives. Biologists must clearly define these objectives to the timber manager, specifying unit size, location, postsale treatments, and road management requirements. Disturbances associated with open roads may significantly diminish project benefits. Project work and the desired site preparation should be scheduled to optimize vegetation response and to avoid critical seasons of bear use. Biologist participation in all phases of project planning, from documentation of objectives in the Environmental Analysis Report, to formulation of the conceptual design and unit layout, will increase the probability of meeting project objectives.

In the following examples, patch cuts (small clearcuts) were used to increase the size of existing foraging components or to create new ones.

Ross Creek spring range project.--The project site was a densely timbered hemlock/beadlily stand ($\bar{x}$ canopy closure = 98 percent) with predominantly western redcedar (Thuja plicata) overstory and a depauperate understory (less than one percent vegetation ground cover). At an elevation of 2,900 ft (884 m) the site is basically flat and lies adjacent to an open low-gradient stream bottom component within occupied grizzly bear habitat. The component has a heavy cover layer of forbs and graminoids, and is punctuated by several small islands of cedar. Bear foods are abundant and include cow parsnip (Heracleum lanatum, angelica (Angelica spp.), sweet sicily (Osmorhiza chilensis, O. occidentalis), horsetail (Equisetum spp.), falsehellebore (Veratrum viride), and numerous other forbs, grasses, and sedges. The component is heavily used by bears during spring for feeding and day bedding. Project objectives are (1) to increase the size of this high-quality spring range, (2) to determine if artificial seeding will significantly accelerate forage establishment and productivity, and (3) to close off the small road which accesses the area.

Three 0.3-acre (0.12-ha) patch cuts were laid out in portions of the timbered stand which most closely approximated the elevation and water table of the adjoining component. The units were logged in the winter of 1983-84 and now await site

preparation. One unit is scheduled for mechanical scarification; and the other two will be broadcast burned. One-half of the scarified unit and one of the burned units will be seeded with umbels. The forested edges of units to be seeded will be broadcast with Osmorhiza occidentalis (commercial seed); the remainder of these units will be seeded with Heracleum and Angelica (collected on site). Differences in seeding location by species are based on the apparent preference of Osmorhiza for a light overstory canopy. Seed collection will occur in fall when seeds are plump and completely dry. Seeding will also occur in fall, before snowfall, and at an application rate of about 6 lb/acre (6.7 kg/ha). A permanent transect containing a series of 10.8 ft^2 plots (1 m^2) located 6.5 ft (2 m) apart, center to center, will be placed to monitor each of the four treatments (burned-seeded, burned-unseeded, scarified-seeded, and scarified-unseeded).

One crew day (3 person-days) is required for seed collection and one crew day for broadcasting. Four days were programmed for project reconnaissance and monitoring. Funding has been appropriated from Sale Area Improvement Funds (Knutson-Vandenburg [K-V]). The total project cost is estimated to be about $800. Human access will be controlled with a tank trap, which will be placed by the timber sale purchaser under a contractual agreement.

In another area (Gordon Creek), an umbel-seeding project has been recently completed. The drainage is similar to Ross Creek in habitat type, elevation, aspect, and water table but differs in its general paucity of spring bear foods and complete absence of an umbel seed source. Two riparian units of 7 acres (2.8 ha) were placed more than 0.5 mi (0.9 km) off a closed road. The units were logged and mechanically scarified in 1983. Slash piles were burned in fall of 1984, and a total of 0.5 acres (0.2 ha) of streamside area within the units was seeded in spring of 1985 with Heracleum and Angelica (collected from the Ross Creek site). Seed was broadcast at a rate of 6 lb/acre (6.7 kg/ha). These units will be monitored similarly to those at Ross Creek to determine project effectiveness.

A crew of three collected seed for 4 hours, and seeding was accomplished by volunteers. The total project cost of $300 included 2 days of monitoring.

Poorman Creek spring range project.--The Poorman Creek project site was also a densely forested hemlock/beadlily habitat type on flat terrain at about 3,000 ft (914 m) elevation. The area coincides with prime grizzly bear habitat but lacks the well-developed riparian vegetation characteristic of the Ross Creek site, and is completely devoid of bear foods. The objective of this project is to create spring range components through placement of three 1-acre (0.41-ha) clearcuts. The units were logged and the sites prepared in the summer of 1981. Slash was mechanically piled, effecting 40 to 50 percent ground scarification.

Permanent transects containing twenty 10.8 ft^2 (1 m^2) plots will be placed in each unit and read this summer. Monitoring to date has consisted of visual walk-throughs and placement of photopoints. Three years following project completion, the sites have approximately 100 percent herbaceous cover, composed predominantly of spring bear forages such as sedges, grasses, umbels, thistles (Circium sp.), and a variety of forbs. The benefit of increasing feeding site availability is compounded by site proximity to cover and by the lack of human access. This project did not require K-V or other wildlife dollars.

BURNING

Fire can also be an effective tool for directly improving habitat (Martin 1979; Zager 1980) but project objectives must be clearly defined and conveyed to the fire manager. Of particular concern are fuel loading and continuity, soil moisture, timing, and vegetative phenology.

Approximately 3,500 acres (1,416 ha) of wildlife habitat are prescription burned annually on the Kootenai National Forest. The emphasis of these projects is primarily to improve the quality of ungulate winter ranges. Following are two examples of burns which focus more heavily on promoting forage opportunities for grizzlies. Neither of these projects has been quantitatively monitored to determine changes in bear food diversity or abundance.

A series of at least twenty 43.2 ft^2 (4 m^2) circular plots may be adequate for sampling the relative abundance of emerging shrubs (Peek 1984). Plots should be about 20 ft (6 m) apart and be placed along a linear transect running diagonally across the slope. Each plot can contain a 10.8 ft^2 (1 m^2) circular subplot to describe the percent ground cover of specific forbs and graminoids. This sampling design can also be used to generate production data.

Grizzly Peak burn.--About 75 acres (30 ha) of a high-elevation (5,200 to 6,000 feet, 1,585 to 1,829 m) south-facing slope were scheduled for fall ignition. The site consists mostly of convex graminoid and beargrass (Xerophyllum tenax) sidehill parks, with a small portion of the area (less than 2 percent) in globe huckleberry (Vaccinium globulare) microsites. The habitat type is subalpine fir/beargrass with scree inclusions.

Although the area is used by bears in fall, when berries from huckleberry (Vaccinium spp.) and serviceberry (Amelanchier alnifolia) become available, heaviest bear use occurs in late spring and early summer, on forbs and graminoids (bunchgrasses [Agropyron spicatum, Festuca spp.], and Carex geyeri). The project objective is to stimulate spring forage production. The area was burned in the fall because of the brief opportunity to burn in the spring at that elevation (immediate green-up generally follows snow recession).

The area was burned by hand in October 1981 after the vegetation had been cured out by heavy fall frost. Fire carried evenly on grassy sidehills but failed to generate sufficient heat to affect the moister microsites. Walk-through surveys indicate an excellent response by graminoids, a reduction in junipers (Juniperus sp.), and little or no change in the condition or abundance of beargrass or huckleberry.

A crew of 15 was required to conduct the burn. Total project cost was about $700 ($9.33/acre, $23/ha).

Bobcat Draw burn.--The project site is a 70-acre (28-ha) shrubfield, heavily interspersed with grasses. Predominant vegetation includes serviceberry, ceanothus (Ceanothus velutinus and C. sanguineus), willow (Salix spp.), huckleberry, pinegrass (Calamagrostis rubescens), and several bunchgrasses and forbs. The area is rapidly becoming encroached upon by Douglas-fir (Pseudotsuga menziesii) and lodgepole pine (Pinus contorta). At an elevation of 5,000 ft (1,524 m), the site is south-facing and is designated as a Douglas-fir/pinegrass habitat type. Wildlife values are primarily spring bear range and ungulate summer range. Bear foods are mostly graminoids, with a small number of berries available in the fall. Project objectives are to eradicate the encroaching conifers while invigorating the graminoids and shrubs. Burning was scheduled for spring to reduce the risk of catastrophic loss.

A helicopter drip torch was used to burn the area in May 1980. Cursory surveys suggest that objectives were met. Virtually all conifers within the burn area were destroyed. Graminoids and most shrubs (ceanothus, willow, serviceberry, and rose [Rosa sp.]) appear to have responded extremely well, whereas huckleberry, possibly affected by high temperatures, has only recently re-emerged.

Seven people assisted in the helicopter operation, which required about 1 hour. Total project costs amounted to about $300 ($4.30/acre, $10.63/ha).

SEEDING GRAMINOIDS AND LEGUMES

Spring use of graminoids and legumes by bears is well-documented in the literature (Husby and McMurray 1978; Mealey and Jonkel 1975; Mealey and others 1977; Zager 1980). Seeding disturbed areas such as roadbeds, cutbanks, landfills, and timber harvest units is an excellent method of accelerating vegetative recovery and can substantially increase spring bear food quality and abundance. Currently, about 400 acres (162 ha) of the Kootenai National Forest (mostly roads) are seeded with legumes and graminoids each year. Of this, about 10 percent is accomplished specifically with grizzly bear habitat improvement in mind. The opportunities for roadbed seeding are expected to increase as the open road density within identified grizzly bear habitat decreases (as directed in the draft Kootenai Integrated Forest Plan). The significance of this is that for every mile of forest road in place, about 2 acres (0.81 ha) of valuable edge habitat remain out of production. During natural succession, closed roads are slowly invaded, generally with less desirable species such as alder (Alnus spp.). Seeding legumes and grasses is a method of returning these road surfaces to more productive habitat.

Various site-specific factors such as temperature and moisture gradients, soil compaction, and level of human disturbance should be evaluated before a seeding project is undertaken. Seed mixes can be custom designed to suit environmental conditions and should contain a high proportion (greater than or equal to 50 percent) of legumes because they are desirable bear foods (Nagy and Russell 1978; Pearson 1975) and are versatile and hardy (Vallentine 1971). Indigenous grasses and legumes should be included in mixes when available and affordable.

Application rates may vary, depending on germination rates and seed sizes. A typical mild zone mix suitable for bear forage seeding in a hemlock/beadlily habitat type might be applied at a rate of 24 lb/acre (26.9 kg/ha), broken down as follows: white dutch clover (Trifolium repens) 25 percent; alsike clover (Trifolium hybridum) 25 percent; birdsfoot trefoil (Lotus corniculatus) 12.5 percent; smooth brome (Bromus inermis) 12.5 percent; timothy grass (Phleum pratense) 12.5 percent; and orchardgrass (Dactylis glomerata) 12.5 percent. Though more expensive, pure live seed (PLS) increases germination confidence and is therefore recommended.

A good standard commercial fertilizer such as 27-10-5 (N-P-K), applied at a rate of about 200 lb/acre (224 kg/ha), can be helpful in successfully establishing forage seedlings; but this advantage can be short lived if soils are nutrient deficient. Use of a high proportion of legumes can be especially desirable on poor soils because of their ability to fix nitrogen (Vallentine 1971).

Seeding and fertilization costs vary with mix composition, type of fertilizer, and application rate but range typically from $75 to $100/acre ($185 to $247/ha). One person can seed 1 to 2 acres (0.4 to 0.81 ha)/day depending on topography and access. Seeding and fertilization projects in northwestern Montana should be scheduled for spring or fall (Kuennen 1979).

Scarification may be indicated if soils are severely compacted. Heavy machinery, such as a D-7 caterpillar, is best suited for ripping soils to a minimum depth of 12 inches (31 cm). Scarification rates average about 5 acres (2 ha)/hour at a cost of about $50/acre ($124/ha).

When human disturbance could significantly alter the habitat effectiveness of an area or the security of bears using an area, forage seeding should not be considered. In such instances, if

seeding is required to meet other resource objectives, less palatable species such as western wheatgrass (Agropyron smithii), streambank wheatgrass (A. riparium), crested wheatgrass (A. desertorium), perennial ryegrass (Lolium perenne), or any of the coarser oatgrasses (Danthonia spp.) should be used (Jonkel 1985). Fertilization in these situations should be forgone. In all roadbed seeding projects, application of the preferred forage seed mix should be deferred in the first 0.25 to 0.5 mi (0.4 to 0.8 km) above the road closure to insulate the project area from human disturbances.

PLANTING BERRY-PRODUCING SHRUBS

Mixed shrubfield-cutting units are critical late summer-fall foraging components in the Cabinet-Yaak Grizzly Bear Ecosystem (Christensen and Madel 1982). Clearcut areas of suitable habitat types which are not excessively disturbed are conducive to the establishment of important berry-producing shrubs such as huckleberry (V. globulare and V. scopulina) and mountain ash (Sorbus scopulina) (Zager 1980). Conversely, cutting units which are severely impacted by scarification and intense heat will have low densities of these species (Arno 1979; Martin 1979; Zager 1980) and may never become valuable bear habitat components. The objective of the following project is to artificially re-establish berry-producing shrubs in a heavily scarified cutting unit.

Purdy Ridge planting project.--The project area occurs in prime grizzly bear habitat and is characterized as a hemlock/beadlily-subalpine fir/beadlily ecotone with moderate to heavy densities of V. globulare and V. scoparium. At about 4,500 ft (1,372 m) in elevation, the site faces east and consists of 20 acres (8.1 ha) of a 50-acre (20-ha) "bug-killed" stand currently being tractor logged and tractor piled. Scarification is expected to be severe.

The project consists of planting 1,150 stems each of V. globulare and S. scopulina seedlings at a total stocking density of 109 stems/acre (270 stems/ha) or a 20- by 20-ft (6.1- by 6.1-m) spacing. The specific objective is to establish a pioneer population from which the unit can be restocked.

About 0.5 lb (0.23 kg) of ripe Vaccinium fruits will be collected this fall from adjacent stands and shipped to a commercial nursery for germination and rooting in tube packs. Eight- to 12-inch Sorbus seedlings will be purchased from commercial nursery stock. Planting is scheduled for spring of 1987. The access road will be closed contractually 1.5 mi (2.4 km) from the site and seeded. Transects containing 50 marked individuals of each species will be surveyed annually to determine percent survival. Additionally, standard 0.1-acre (0.04-ha) plots will be placed within the planted and unplanted (control) portions of the unit to generate information on shrub densities and community structure.

Seed collection and planting will require about 11 person-days (at a planting rate of 2 acres [0.81 ha]/person/day). Total project costs (funded through K-V) including planting stock ($0.65/stem) and 4 days of monitoring are expected to be $2,600 or $130/acre ($320/ha). The 2 acres (0.81 ha) of road seeding will cost about $150.

CONCLUSIONS

The merits of direct habitat improvement projects such as those described can be challenged on the basis of their undetermined biological or cost effectiveness. Other factors, however, appear to be certain: the amount of effective high quality grizzly bear habitat will continue to decrease as private land development, road construction, minerals exploration and development, recreational pressure, and more intensive timber management increase.

Opportunities to stem the cumulative impacts from these activities must be taken on all fronts, whenever possible. This is particularly critical at a time when funding levels, which have historically been inadequate, continue to decline. Sale Area Improvement Funds (K-V), although not a panacea, still provide the best opportunity to finance projects. Sale areas proposed in grizzly bear habitat, particularly in habitat allocated to meet grizzly bear management objectives, should be carefully assessed for K-V project potential.

Research is needed to validate the effectiveness of different treatments but forest management must go on in the interim. Wildlife biologists involved in forest management cannot wait for conclusive evidence. Project opportunities are either aggressively sought out or they are lost. Professional judgment and available information must suffice; biologists can use verified habitat improvement techniques on a large scale (for example, burning) and creatively seek new projects to try on a smaller scale.

Biologists need to design practical but inexpensive methods of monitoring the effectiveness of their projects--not to take the place of research but to allow them to evaluate their efforts more objectively. The research and academic communities need to acknowledge the potential of proactiv habitat manipulation and to direct more applied research toward developing appropriate procedures.

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GRIZZLY HABITAT IMPROVEMENT PROJECTS ON THE SOUTH AND MIDDLE FORK FLATHEAD RIVER

Thomas M. Holland

ABSTRACT: The South and Middle Forks of the Flathead River contain areas of prime grizzly bear (Ursus arctos horribilis) habitat. Between 1978 and 1984, the Spotted Bear and Hungry Horse Ranger Districts conducted habitat improvement projects designed to benefit the grizzly bear and other wildlife species. These improvement projects include prescribed burning, clover seeding, plantings, openings, and road closure programs. The helitorch has proven to be the most effective method for prescribed burning, and the cost has been approximately $15 to $20 per acre. First growing season regrowth response has been as much as 60 inches for some browse species such as willow, which is an important big game food in this area. Maintenance of large big game herds is important to the grizzly bear because they ensure a continued source of carrion. Clover seeding costs about $6 per acre, and effectively provides early season bear foods. An intensive road closure program has been implemented, and on one timber sale area the open road density was reduced 50 percent as a result of the sale.

INTRODUCTION

The South and Middle Forks of the Flathead River lie within prime occupied grizzly bear habitat in the middle of the northern Continental Divide Grizzly Bear ecosystem, which contains an estimated 440 to 680 grizzly bears (U.S. Department of Interior, Fish and Wildlife Service 1982). The Flathead National Forest staff estimates that approximately 150 to 180 grizzly bears live on Flathead National Forest lands within the area drained by the three forks of the Flathead River (U.S. Department of Agriculture, Forest Service 1983). The South Fork of the Flathead drains an area of approximately 1,663 mi^2, and is administered entirely by the Spotted Bear and Hungry Horse Ranger Districts. No private land exists within the entire drainage. The Middle Fork of the Flathead drains an area of approximately 1,128 mi^2, and is generally administered by the Flathead National Forest south of U.S. Highway 2 and by Glacier National Park north of U.S. Highway 2. Scattered low-elevation private inholdings occur throughout the length of this river valley.

The area outside designated wilderness, particularly within the South Fork, is under intensive timber management with approximately 25 to 30 million board feet of timber harvested annually. The area was first roaded in the mid 1950's and during the 1960's and 1970's the area was subject to widespread logging and roading.

Grizzly bear densities are estimated to be high in some areas of the South and Middle Fork drainages. Within one study area, consisting of 128 mi^2 in the South Fork, there was an autumn density estimate of one grizzly bear per 9.8 miles (Mace 1980).

GRIZZLY BEAR HABITAT IMPROVEMENT PROJECTS

Habitat management techniques that simulate habitat components known to be important to the grizzly bear have the potential to improve habitat. These projects are funded by Forest Service wildlife funds and K-V dollars which are collected from the sale of National Forest timber.

Little, if any, information has been reported or published about improving habitat for the grizzly bear, however, the Spotted Bear and Hungry Horse Ranger Districts have been successfully experimenting with a number of techniques. These includ prescribed burning, clover seeding, aspen planting browse planting, lodgepole pine conversions, and road management. The following list shows the projects and the acres treated since 1978:

Habitat improvement	Acres treated
Clover seeding	1,418
Prescribed burning	1,230
Lodgepole pine conversions	280
Aspen/browse planting	200

Natural fires, under prescription, within the Bob Marshall and Great Bear Wilderness areas will be allowed to burn and, in addition, create vegetative mosaics which will directly benefit the grizzly bear. The projects also emphasize logging practices such as broadcast burning, which have been shown to minimize damage to the root systems of key bear foods.

PRESCRIBED BURNING

Winter ranges within the South and Middle Forks of the Flathead provide winter forage for most of the Flathead National Forest's elk (Cervus elaphus) herd, which numbers over 4,000 animals. In addition, mule deer (Odocoileus hemionus), white-tailed deer (Odocoileus virginianus), moose (Alces alces), and mountain goat (Oreamnos americanus) winter on these ranges. Maintenance and improvement of these winter ranges for big game should

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continue to benefit the grizzly bear because their dependency upon carrion in spring following den emergence has been well documented. Mealey (1977) found in Yellowstone that during the early spring season grizzlies are primarily meat-eaters. They congregate on ungulate winter ranges and eat available animal material. Studies done in Northwest Montana and the South Fork of the Flathead also substantiate this preference for carrion. Mace (1984) noted the importance of ungulate winter ranges and valley bottoms, which grizzly bears travel regularly in spring when searching for carrion. Jonkel and others (1980) speculate that this food source may be particularly important to vulnerable subadult bears. In addition to carrion, weakened or otherwise vulnerable animals are occasionally taken by grizzlies. Big game carrion, particularly elk and mule deer, are an important nutrition source for grizzlies in the South and Middle Forks in the spring, as evidenced by the use of carcasses from late April to early June (Holland 1985). Mealey (1977) feels that the pregrowing season in Yellowstone is the only time when the bears' supply of protein may be strictly limited. He speculated that this period is likely to be the primary one in which natural grizzly bear population regulation occurs.

Winter range areas also contain a number of fruit-producing shrubs that provide important summer and early fall foods for the grizzly bears. Among the most important foods in the area are blue (globe) huckleberry (Vaccinium globulare), serviceberry (Amelanchier alnifolia), buffaloberry (Shepherdia canadensis), chokecherry (Prunus virginiana), mountain ash (Sorbus scopulina), and dogwood (Cornus stolonifera). Probably the most important fruit-producing shrub on these winter ranges is serviceberry. Grizzlies have been observed feeding on serviceberry fruits in late summer (Holland 1985).

The objective of prescribed burning is to immediately rejuvenate browse species important to big game and grizzly bear and to prevent coniferous tree seedlings from invading brush fields. Between 1978 and 1984, the Spotted Bear and Hungry Horse Ranger Districts conducted prescribed burning on over 1,230 acres of the South Fork big game ranges, on which grizzlies also depend. Spring burning is a common and accepted practice to rejuvenate seral shrubfields and is less expensive than fall burning because minimal control measures are necessary. Spring burns have been performed between early March and mid-May, depending on elevation and weather conditions, because the best burning conditions occur then. Burns conducted in May are less effective because green vegetation inhibits fire spread. One fall burn was conducted but was not as effective as the spring burns because fuels in the lower elevation burn areas had not adequately cured. Most fires are started with a helicopter drip torch; however, a few are ignited by hand. The helitorch method has proven to be the most effective method because of steepness of slope and inaccessibility. Burns averaged over 200 acres per year and cost between $15 and $20 per acre. In 1985 four burns, totalling approximately 350 acres, are scheduled on the two Districts.

Vegetation burned on Horse Ridge on April 16, 1984, was measured again on August 16, 1984, to determine the average height of resprouting 4 months after burning. Fire totally removed the above-ground portion of the plants and as much as 60 inches of regrowth was recorded on some species. The following list shows the average species response to fire on the Horse Ridge Burn of 1984:

Browse species	Average height of regrowth August 16, 1984
	Inches
Amelanchier alnifolia (serviceberry)	28.5
Acer glabrum (mountain maple)	36.25
Betula papyrifera (paper birch)	40.0
Ceanothus sanguineus (redstem ceanothus)	31.75
Ceanothus velutinus (evergreen ceanothus)	17.0
Populus tremuloides (quaking aspen)	33.5
Prunus virginiana (chokecherry)	33.0
Salix spp. (willow)	55.5

WILDERNESS PRESCRIPTION BURNS

Fire suppression for the past 60 years has changed the vegetative mosaic within the Bob Marshall ecosystem and has substantially reduced the quantity of early successful stages of vegetation. Effective fire suppression since 1920 has therefore negatively affected grizzly bear habitat and food production on mesic sites in northwestern Montana. As conifers encroach and the vegetation community develops in vast areas of seral, shrub-dominated plant communities created from wildfires, production and canopy cover of certain bear food plants may decline. According to Zager (1983) this eventually produces old-growth forests with closed canopies where bear food production is relatively low.

Natural wilderness prescription fires and planned ignition, which may be approved in the near future, will help reverse the loss of seral-dominated brushfields, where globe huckleberry is common. In areas where fire or other disturbances have been absent, huckleberries are gradually crowded out by invading trees or other vegetation (Minore 1972).

Huckleberries are a major component of grizzly bear diets on the Flathead National Forest from late July through September. Martin (1980) found that the most productive huckleberry sites were

located on mesic north or east aspects, which were burned by wildfire 25 to 60 years ago, or on 8- to 15-year-old clearcuts that were broadcast burned to reduce slash. Therefore, long-range planning is necessary to assure the continued production of globe huckleberry fruit crops on grizzly bear habitat.

In June 1983 a wilderness fire plan was approved for the Bob Marshall and Great Bear Wildernesses. This plan would allow fires that meet specific criteria to burn without human interference. In 1984, the first full year of implementation of the plan, eight fires were allowed to burn; however, only three of the eight exceeded spot size and together totaled 165 acres.

CLOVER SEEDING

Trifolium (clover) and other herbaceous vegetation were among preferred plant foods and constituted a high proportion of the plant food consumed by grizzlies within a study area in the Scapegoat Wilderness of Montana (Craighead and others 1982). Mealey (1977) found that in the Yellowstone area, succulent new grass is the earliest and most important food eaten by grizzlies in the spring after they emerge from dens. He found that white clover was extensively used where it was abundant and associated with other bear foods.

Since 1980, just over 1,400 acres of disturbed logging sites such as landings, skid trails, and obliterated roads have been seeded with clover within the South Fork of the Flathead River. Although clover is a favorite grizzly food from early May to early July, seeding occurred only behind road closures to minimize encounters between feeding bears and humans--encounters that often result in the death of a grizzly. Clover seeding generally costs about $6 per acre when seeding at a rate of 3 pounds per acre.

ASPEN AND BROWSE PLANTINGS

Aspen and browse have been planted on approximately 200 acres of disturbed logging sites. Aspen, black cottonwood, and other fast-growing deciduous species are planted around springs and wet sites to provide cover that grows quickly. These moist sites have been recognized as important microsites for the grizzly bear. These species also provide diversity in the sometimes monotypic coniferous forest regeneration found on logged sites. Serviceberry and chokecherry have also been planted on suitable sites within sale areas frequented by grizzlies. Aspen and browse seedlings are planted for approximately $25 per acre. The cost of the seedlings comprises the majority of this cost because they are planted by volunteers.

LODGEPOLE PINE CONVERSIONS

Portions of the South and Middle Forks of the Flathead contain extremely dense stands of lodgepole pine that are a result of the intense wildfires of the early 1900's. These stands are stagnated, have a high number of stems per acre, and contain little or no understory vegetation. In 1978 a few small patches of this timber type were slashed and burned so that browse and grass would invade the openings and provide supplemental forage for wildlife.

Since 1980 approximately 130 acres of stagnated lodgepole pine in the South Fork and 150 acres in the Middle Fork drainages have been sold for posts and poles or piled and burned directly when no market existed. These areas are then replanted with a mixture of tree species, including some hardwoods. This treatment increases timber potential of the site while providing for wildlife diversity. This treatment can be expensive if the wood products cannot be sold.

ROAD CLOSURES

Timber harvest and roading increased greatly about 1960 in the South and Middle Forks of the Flathead River. Most of these roads remained open until the mid-1970's and early 1980's, when a concerted effort was made to reduce the number of open roads to protect wildlife, particularly the grizzly bear. The negative effect of open roads on elk and grizzlies is well documented (Lyon and others 1985; Mace 1984).

Information collected by Zager (1980) from four radio-collared grizzly bears in northwestern Montana indicates that grizzlies generally avoid areas where trees have been harvested and where roads are open to motorized use. Bear use in these areas is restricted to certain areas along secondary roads or where roads have been closed.

In a study on the west side of Hungry Horse Reservoir, Jonkel and others (1980) found that two of the 10 South Fork Flathead grizzlies marked during the 1975 to 1978 study were subsequently illegally killed.

In 1983 three female grizzly bears were illegally killed on the east side of Hungry Horse Reservoir. This occurred in two separate, unrelated incidents only 1 day apart. Two of the three grizzlies were adult females with cubs; the other was a female cub. These incidents occurred during the spring black bear hunting season. These statistics support the view that many grizzlies are illegally killed in the South Fork of the Flathead. This may occur because a relatively high number of grizzlies inhabit low-elevation roaded areas in the spring, which makes them likely targets for accidental killings by black bear hunters or intentional shooting by poachers.

As a result of these illegal kills, the Spotted Bear and Hungry Horse Ranger Districts have intensified their efforts to reduce the number of miles of open roads in prime grizzly bear habitat, thus providing secure habitat for the bear and greatly reducing the risk of illegal kills. Roads are either seasonally closed during critical time periods or are permanently closed. For example, in 1984, 10 gates were installed which seasonally or permanently closed a total of 58 miles of road.

Since 1982, approximately 200 miles of road have been seasonally or permanently closed to vehicle use. This is in addition to other roads which are closed in conjunction with individual timber sales. With each new timber sale proposal a transportation plan is developed for that area, usually by a major drainage, to determine what roads will be kept open. Dollars generated through these timber sales are used to close the roads by means of a gate, physical barrier, or cement structures called New Jersey guardrails.

An example of how a timber sale can improve habitat for grizzly bears and other wildlife occurred when the Hungry Horse Ranger District sold an 11 million board foot sale in 1984 in the Middle Fork Drainage. Before this sale, a total of 38 miles of roads (30 open, eight closed) accessed the area. The 8 miles of new road construction necessary to access new logging units increased the total to 46. Gates and road closures were put in place even before actual logging began. Of the 46 miles of road, 28 were then permanently closed, leaving only 18 miles of open access roads, a net loss of 12 miles from what existed before the sale. Figure 1 compares the amount of open road before and after the sale. Most of the 18 miles left open is the main arterial road traversing the area. Road closures thus reduced the open road density from approximately 1 mile of road per square mile before the sale to 1/2 mile of road after the sale. Gates on roads used to haul logs were purchased and installed by the timber sale purchaser. Without timber sale activities to generate dollars to close these roads, many would remain open until other funding sources were made available. Currently 112 structures exist in the zone and effectively close over 400 miles of road.

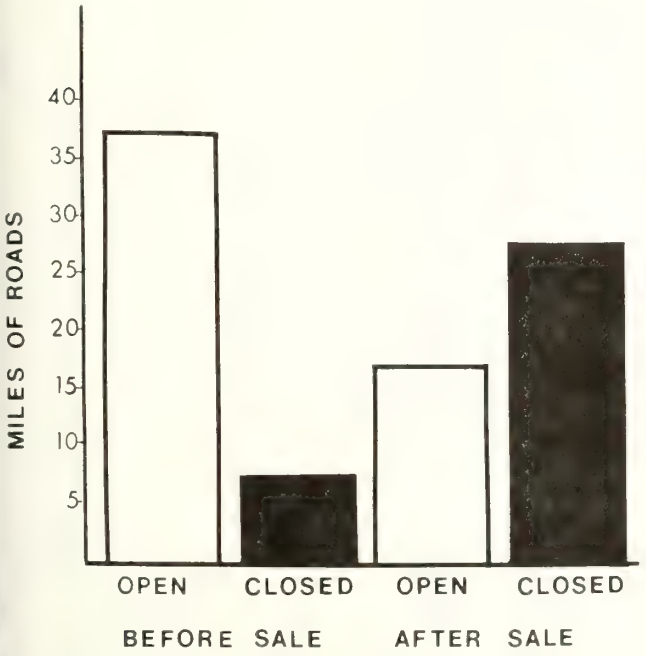


Figure 1.--Miles of open and closed roads before and after the Middle Fork lodgepole sale.

CONCLUSIONS

Based on our knowledge of grizzly bear food preference and their need for isolation from humans, we can assume that our grizzly bear habitat improvement program is a positive step to enhance and protect grizzly bear habitat. We still need to develop well-planned and documented long-range studies to evaluate these efforts. This information will provide evidence of the benefits derived from these improvement projects.

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COORDINATING LIVESTOCK AND TIMBER MANAGEMENT WITH THE GRIZZLY BEAR IN SITUATION 1 HABITAT, TARGHEE NATIONAL FOREST

Mark L. Orme and Robert G. Williams

ABSTRACT: Adjustments were made in the timber and livestock management programs to accommodate the needs of the grizzly bear in Situation 1 habitat. Some of the major adjustments in the timber management program include reducing cutting unit size; using silvicultural prescriptions to benefit understory forage plants; increasing the size of leave strips; road closures; cover objectives that would not decline below 50 percent; and maintaining security areas of at least 5,000 acres. Some of the major adjustments in the livestock management program include closing four sheep allotments; converting one sheep allotment to a cattle allotment; full-time monitoring of all sheep allotments; restricting methods of handling bear predation problems; and removing sheep from an allotment in cases of conflict.

INTRODUCTION

One of the longest historical uses of the Targhee National Forest has been domestic livestock grazing; in some areas, grazing predated the creation of the National Forest. When the grizzly bear (Ursus arctos) was classified as a threatened species, historical grazing uses and public attitudes were in conflict with the immediate needs of the bear. Intensive timber management on the Targhee has been a more recent event, beginning mainly in the 1960's. Approximately half of the timber base on the Targhee is lodgepole pine (Pinus contorta), and about 90 percent of the pine was mature. The mountain pine beetle (Dendroctonus ponderosae) began killing large numbers of trees in the late 1960's and 1970's. The Forest subsequently began a salvage program, which in some cases was in conflict with the needs of the bear. This paper presents an overview of grizzly-livestock-timber coordination that has occurred on the Targhee National Forest since 1975, when the bear was officially listed as a threatened species under the Threatened and Endangered Species Act. It describes changes in livestock grazing and timber management, along with formal consultations that have occurred with the U.S. Department of the Interior, Fish and Wildlife Service.

Paper presented at the Grizzly Bear Habitat Symposium, Missoula, MT, April 30 - May 2, 1985.

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LOCATION

Grizzly bear Situation 1 habitat is located in two areas of the Targhee National Forest (fig. 1). One area lies in the northeast corner of the Forest and occupies 35,960 acres. This area includes the Henry's Lake Mountains north and east of Henry's Lake. The boundary follows the Continental Divide, which is also the Idaho-Montana state line. The area is characterized by high glaciated mountains rising to 10,000 ft elevation. Vegetation varies from heavy lodgepole pine and Douglas-fir (Pseudotsuga menziesii) timber stands in the lower elevations to subalpine and alpine vegetation in the middle and upper elevations. Perennial streams and springs occur throughout the area. Domestic livestock grazing has been the predominant resource use; timber harvest has been limited; and recreation use is considered light during the summer, with increasing use during the fall hunting season and high use during the winter snowmobile season.

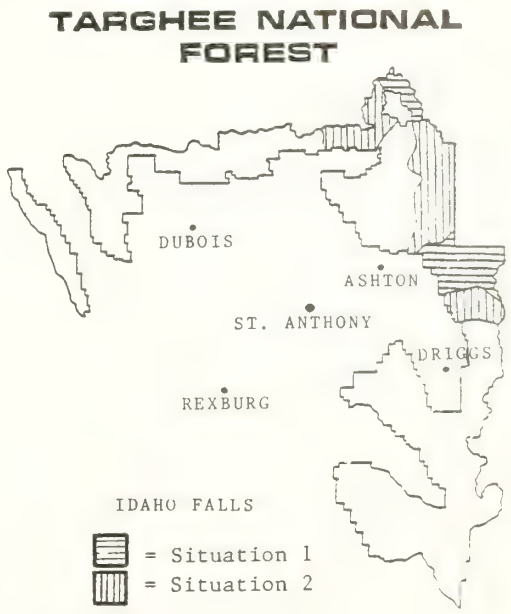


Figure 1.--Situation 1 and 2 grizzly bear habitat.

The second area lies along the southern boundary of Yellowstone National Park and occupies 138,140 acres. Elevations range from 5,600 ft on the western edge to 9,200 ft on the eastern side. The western portion of this area is

characterized by large lodgepole pine uplands and plateaus, dissected by gorgelike canyons. Shallow lakes and marshes are scattered throughout the area. The principal timber type is lodgepole pine; however, Douglas-fir grows along the canyon ridges and north facing canyon slopes. The lodgepole pine stands have undergone severe attack from the mountain pine beetle, and large areas have been salvaged. Cattle and sheep grazing occur within the area.

This second area includes the newly created Winegar Hole Wilderness adjacent to the southern boundary of Yellowstone National Park. Numerous ponds, seeps, meadows, shallow lakes, and streams are dispersed throughout the area. These aquatic and riparian habitats are surrounded by extensive stands of lodgepole pine, aspen (Populus tremuloides), Douglas-fir, and subalpine fir (Abies lasiocarpa). The dominant human use is for recreation.

The eastern portion of this second area is part of the newly created Jedediah Smith Wilderness. The area is characterized by high-elevation, glacially scoured ridges and basins perched above U-shaped canyons. Scattered patches of subalpine fir, spruce (Picea engelmannii), Douglas-fir, and whitebark pine (Pinus albicaulis) are interspersed through natural forb and grass meadows. The dominant human use is recreation and livestock grazing.

RECENT GRIZZLY BEAR USE

Forest personnel have annually compiled a list of grizzly bear sightings. Figure 2 summarizes the sightings from 1965 through 1984.

Documentation of grizzly bear-livestock-human interactions on the Targhee National Forest has been accomplished through several research studies and agency reports (Jorgensen and Allen 1975; Jorgensen 1979, 1983; Griffel 1981; Knight and Judd 1983; U.S. Department of Agriculture, Forest Service 1981-1984). These studies and reports document consistent human-bear-sheep interactions and incidents. These studies and reports have shown only an occasional interaction between cattle and grizzly bears, with no human-bear incidents occurring as a result of cattle grazing.

No studies have analyzed the effects of logging on grizzly bears on the Targhee National Forest. However, Interagency Grizzly Bear Study Team research has identified grizzly bear-habitat relationships in the Yellowstone area (Blanchard 1983). Interagency Guidelines have been developed for coordinating timber management with grizzly bear needs. (USDA, Forest Service 1979, 1982). Verified grizzly bear sightings have occurred in timber sale areas before, during, and following harvest activities. No verified human-bear incidents have been associated with logging.

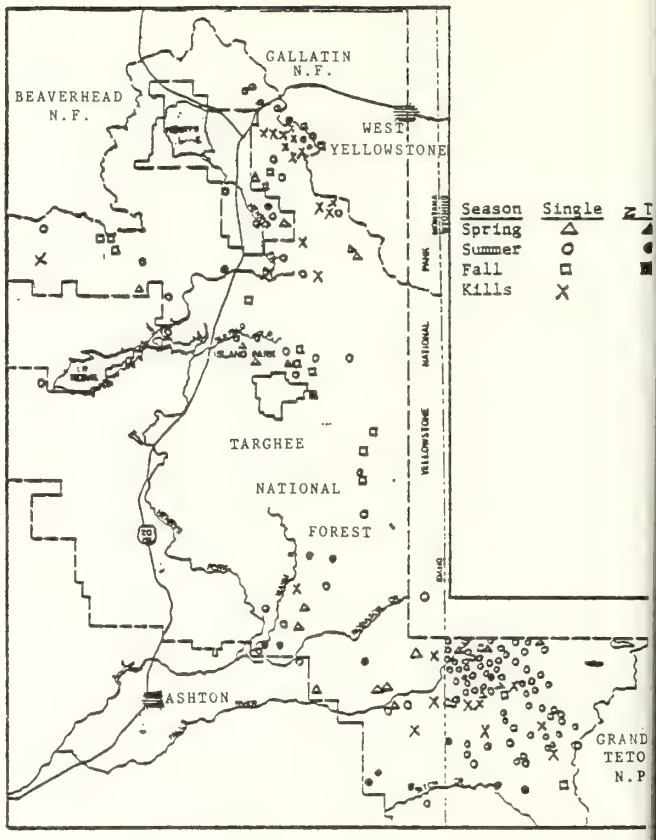


Figure 2.--Summary of grizzly bear observations on the Targhee National Forest, 1965-84.

TIMBER MANAGEMENT--1975 to 1985

Intensive timber management on the Targhee began in the 1960's. Approximately half of the timber base on the Forest is lodgepole pine; a large percentage (80 to 90 percent) of the pine was in a mature timber class by the 1960's and 1970's. The mountain pine beetle began killing large numbers of trees in the late 1960's and 1970's. Early timber management techniques involved selection cutting to remove only the trees killed by the beetle. This type of cutting opened up many timber stands and created favorable conditions for understory shrubs and grasses but generally did not encourage regeneration of lodgepole pine. Clearcutting of stands followed by extensive mechanical soil scarification is the technique used now to regenerate stands.

Timber management was the first program to recei formal consultation with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act. In 1978, a "no jeopardy opinion" was received with the timber management program, providing certain management actions were implemented in a "discreet manner." The following is a summary of the recommended management actions:

1. Miles of road in areas of grizzly use (Situation 1 habitat) should remain at or below the present (1978) number.

2. Heavy concentrations of dead trees resulting from the pine beetle epidemic could cause multi-thousand acre fires, which would be detrimental to the cover needs of the bear. Timber harvesting to break up this fuel loading was considered beneficial with the following recommendations:

a. Selection cuts should be used wherever and whenever possible and clearcuts should be minimized. Understory forage species, such as tall huckleberry (Vaccinium globulare), would be protected and possibly enhanced with selection type cutting.

b. When they are necessary, clearcuts should be irregularly shaped to increase ecotonal areas and should not exceed 100 meters across. Where clearcuts are used, soil scarification should be minimized by broadcast burning slash whenever possible; dozer piles should be kept small and placed in areas most severely impacted by machinery.

c. Uncut strips or cover strips should be left around clearcuts and around open grizzly feeding sites such as avalanche chutes, meadows, shrubfields, sidehill parks, and creek bottoms. To assure cover adequacy, cover strips, even in the form of dead standing or fallen trees should remain.

d. When possible, logging should be restricted to the winter months in areas having abundant bear foods (generally large mesic sites) to reduce soil scarification, which destroys rhizomatous plants and root crowns of some shrubs.

e. When more soil scarification is required for conifer regeneration than is obtained in the above slash disposal methods, scarification should be restricted to highly disturbed sites or to a strip configuration through the clearcuts.

The Targhee National Forest is often called the "pocket gopher capital of the world," and successful regeneration of cutting units often will not occur until intensive gopher control work is completed. The most commonly used technique for pocket gopher control is to use 0.5 percent strychnine-treated oats placed underground in burrows at a rate of 1/2 to 1 1/2 lb/acre the first year of treatment, and 1/4 to 1/10 lb/acre the second and third years.

With regard to this part of the timber management program, the 1978 formal consultation recommended that strychnine bait not be used to control pocket gophers in grizzly bear biological centers. The Environmental Protection Agency, however, had previously determined that underground use of strychnine bait did not significantly increase the risk to nontarget wildlife (Hegdal and Gatz 1976).

In 1979, the Forest Service reinitiated formal consultation with the Fish and Wildlife Service in order to address the potential hazards of this program for the grizzly bear. To adequately assess the potential hazards, biologists from the Denver Wildlife Research Center designed and conducted a study. At the conclusion of this research, a biological opinion was received that the use of strychnine grain bait underground is not likely to jeopardize the continued existence of the grizzly bear. In issuing this opinion, the following additional conservation measures were recommended:

1. An area should be reforested as soon after harvest as possible. Immediate reforestation reduces problems with pocket gophers and the amount of strychnine needed.

2. The feasibility of other control techniques such as vexar tubes or zinc phosphide should be explored. This research has subsequently been completed (Barnes and Evans 1982; Anthony and Barnes 1978).

3. Areas scheduled for treatment should be thoroughly surveyed for evidence of grizzly use such as tracks, diggings, or actual sightings. If grizzly use is noted, treatment plans should be delayed until the bears leave the area. If grizzly use becomes evident after baiting has commenced, treatment should be halted immediately.

4. Baiting procedures by contracted crews should be closely regulated and inspected by the Forest Service to ensure that the minimum amount of grain is deposited in each bait set and in each treatment site. Penalties should be assessed for too many sets and too much grain in each set. The Forest Service should consider developing a tool to administer a predetermined amount of baited grain per set when setting bait by hand.

Following these two formal consultations with the Fish and Wildlife Service, the Targhee National Forest in 1980 began to develop the Forest Land Management Plan. For the purpose of simplicity, the discussion of how timber management and the needs of grizzly bear were coordinated in the Targhee Forest Plan is confined to the Situation 1 habitat area south of Yellowstone National Park (fig. 1). This management area contains extensive stands of lodgepole pine, most of which are dead or dying and will be lost to commercial use if not salvaged within the next 15 years. In addition to the obvious loss of products if salvage operations were not undertaken, future productivity is jeopardized as the untreated and dying stands naturally regenerate at a much slower rate than treated stands. In addition, untreated stands become infested with mistletoe from the residual overstory.

A first step in the coordination of timber with grizzly bear needs was to inventory the timber resource and to determine exactly how much was available. The inventory identified 50,000 acres of mature lodgepole pine on slopes less than 40 percent that could conceivably be harvested while maintaining acceptable soil and water conditions. In this management area, as in several others, the planning team did not consider salvage of lodgepole during the first decade (1981-1990) in areas where advanced logging systems would be required, because massive amounts of dead material were available for salvage in more economically and environmentally suitable areas.

It was estimated that the 50,000 acres of mature lodgepole would yield 350 million board feet; however, because most of the lodgepole was dead and had been for some time, salvage would only be possible during the next 15 years. In planning terms, this level of activity is designated as the maximum unconstrained timber benchmark (fig. 3).

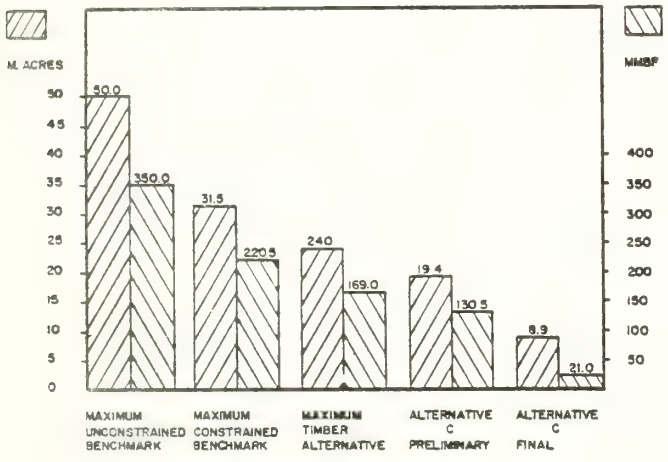


Figure 3.--Acres and volume of lodgepole pine timber management benchmarks and alternatives in Situation 1 habitat south of Yellowstone National Park.

Obviously, it was not possible or desirable to cover the entire management area within 15 years. The interdisciplinary team evaluated the minimum needs of other resources such as recreation, range, wildlife, and watershed and concluded that to maintain basic minimum levels of other resource use, the total area and volumes that could be realized during the first decade were 31,500 acres and 220.5 million board feet. This level of activity is designated as the maximum constrained timber benchmark (fig. 3).

Up to this point, the emphasis was on developing baseline data from which alternatives could be developed. These alternatives projected timber outputs ranging from 12,351 to 24,027 acres, and 83.2 to 169.0 million board feet. Alternative C, the preferred alternative, called for treatment of 19,370 acres with a projected volume of 130.5 million board feet (fig. 3).

During a subsequent period of "ground truthing" by ranger district personnel, it became evident that the projections for timber outputs were too high and that they could not be achieved if the needs of the grizzly bear were to be met. Several factors contributed to this perception:

1. The initial reductions for wildlife were based on general wildlife considerations and did not consider the special needs of the grizzly bear.

2. Although there was still a considerable amount of mature lodgepole cover within the area, quality of cover was poor because of limited dispersion.

3. There had been fairly extensive harvest of "dead only" areas, leaving stands of mature lodgepole that contained low volumes and provided limited cover.

4. The level of existing activity had not been carefully balanced against projected future activity and the needs of the bear.

To correct these deficiencies, district personnel stratified the management area by portraying grizzly habitat components and showing precisely where past timber activities had occurred and where future activities were projected.

In addition, the management area was further stratified into "bear subunits" (fig. 4). This stratification allowed planners to better

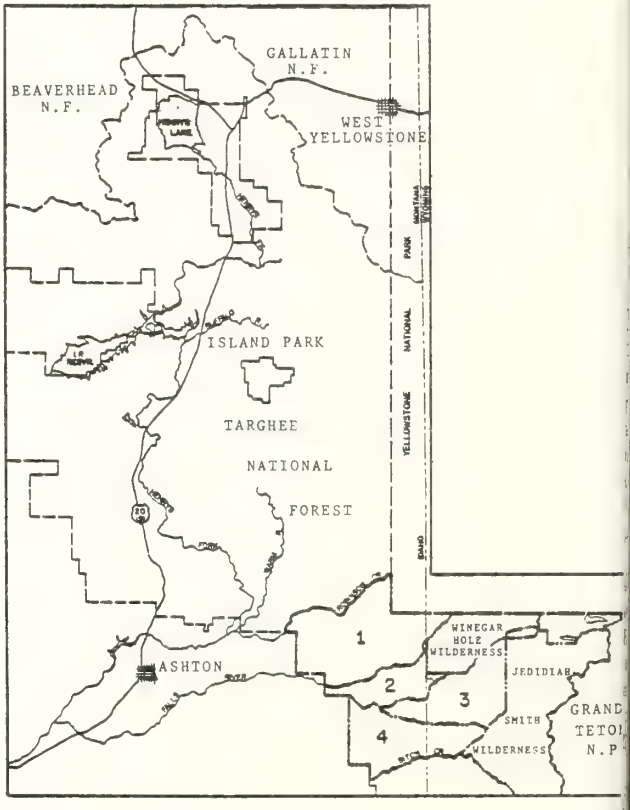


Figure 4.--Situation 1 habitat south of Yellowstone National Park, subdivided into four bear management subunits.

distribute activities and to designate areas where development would not occur until activities in other subunits were concluded.

Specific output levels and cultural practices for timber harvest as well as levels of cover that would be maintained were identified and carried forward as management direction in the Land Management Plan as follows:

1. Harvest timber and other products, reforest cutover areas, and accomplish timber stand improvement and silvicultural examination during the first decade as shown in table 1.

2. The following cultural practices apply to lodgepole pine stands:

Area	Maximum size clearcut	Minimum average width of leave strip
	Acres	Feet
Elk summer concentration areas	40	1/ 600
Elk calving areas	40	1/ 600
Elk/deer winter range	40	1/ 600
Situation 1 grizzly bear habitat	2/ 40	1/ 800

3. Concentrate all timber management activities within the shortest time period and smallest possible area.

4. Maintain security areas of at least 5,000 acres within subunits 1, 2, 3, and 4 for duration of high level of human activity.

5. Manage Situation 1 subunits to provide the following levels of cover:

Subunit	Acres	Conifer cover 3/ 1981	Conifer cover 3/ 1990	Aspen	Unproductive forest
1	32,400	60	66		
2	8,960	65	65		
3	18,080	74	74		
4	19,900	60	65		
Total	79,340	65	66	7	1

lLeave strips having a percentage of dead trees ıigh enough to prevent their serving as cover ıay be harvested before adjacent clearcuts)rovide cover, if contiguous cutting units ıave been planted or naturally regenerated. Natural regeneration will be considered ıccomplished after the third year inspection ·eveals natural regeneration meets stocking evel standards.

Each sale area, and the individual stands ithin, will be evaluated for key grizzly abitat components for final unit size etermination. Clearcut size may exceed 40 cres (up to 100) if cutting unit configuration s such that distance to cover does not exceed)0 ft over 80 percent of the unit.

)oes not include aspen or unproductive forest.

The result was that lodgepole pine harvest was reduced to 8,925 acres with a projected volume of 21.0 million board feet (fig. 3).

Although this level of timber harvest will treat considerably fewer acres of decadent lodgepole than necessary to properly manage timber stands from a purely timber silvicultural standpoint, this strategy is considered necessary to adequately provide for the needs of the grizzly bear.

LIVESTOCK GRAZING--1975 to 1985

Perhaps the oldest resource use occurring on the Targhee National Forest is domestic livestock grazing. Many of the permits for grazing allotments date to the time when the Forest was officially established. Livestock permittees on National Forest lands legally have a contract with the government. Grazing privileges are guaranteed to the livestock permittee as long as the permittee is willing to abide by the conditions of the permit. Permits cannot be cancelled unless violations of the permit requirements occur. In 1975, when the grizzly bear was officially classified as a threatened species, 11 sheep allotments and four cattle allotments were permitted and in use in the areas that were eventually to become Situation 1 grizzly bear habitat (table 2; fig. 5).

Sheep grazing generally occurs from the first part of July until the first part of September (approximately a 72 day grazing period). A sheepherder stays with the sheep full time while they are on the Forest.

Cattle grazing generally begins around the first part of July but continues longer into the fall, generally to the first part of October (approximately a 92 day grazing period). Cattle allotments are fenced into various pastures. Unlike sheepherders, cattlemen are generally not continually with their livestock. Occasional fence mending, herding, and movement of the cattle between pastures is required.



Table 1. Timber management outputs for the first decade (1981-90) in management area 12

Timber type	Acres planned for harvest	Estimated outputs MBF's 1	Acres to be reforested			Acres timber stand improvement
			Backlog	Current cutover (sawtimber)	Current cutover (firewood and other products)	
Douglas-fir	561	2,000	-	-	-	
Lodgepole	3,225	16,000	425	3,200	-	602
Firewood and other products	5,700	5,000	-	-	5,700	

[1]Includes approximately 4,550 acres and 10 million board feet (not a part of target) that may not be available depending on future application of grizzly bear guidelines to on-the-ground conditions.

Table 2. Summary of permitted livestock grazing in situation 1 grizzly bear habitat, 1975

	Allotment name	Type	Permitted grazing use	In Use
1.	Targhee Mountain	Sheep	1,200-ewe band	Yes
2.	East Targhee	Sheep	1,000-ewe band	Yes
3.	Dry Creek	Sheep	850-ewe band	Yes
4.	Jesse Creek	Sheep	850-ewe band	Yes
5.	Reas Pass	Sheep	1,000-ewe band	Yes
6.	Garner Canyon	Cattle	26 AUM's 1	Yes
7.	Twin Creek	Cattle	198 AUM's	Yes
8.	Rock Creek	Sheep	700-ewe band	Yes
9.	Fall River Ridge	Cattle	2,420 AUM's	Yes
10.	Squirrel Meadows	Cattle	4,699 AUM's	Yes
11.	Dog Creek	Sheep	1,000-ewe band	Yes
12.	Squirrel Meadows	Sheep	1,000-ewe band	Yes
13.	South Boone	Sheep	1,000-ewe band	Yes
14.	Grizzly Creek	Sheep	1,000-ewe band	Yes
15.	Middle Bitch Creek	Sheep	1,000-ewe band	Yes

Total: 11 sheep allotments in-use: 10,600 ewes
4 cattle allotments in-use: 7,343 AUM's

[1]Animal unit months.

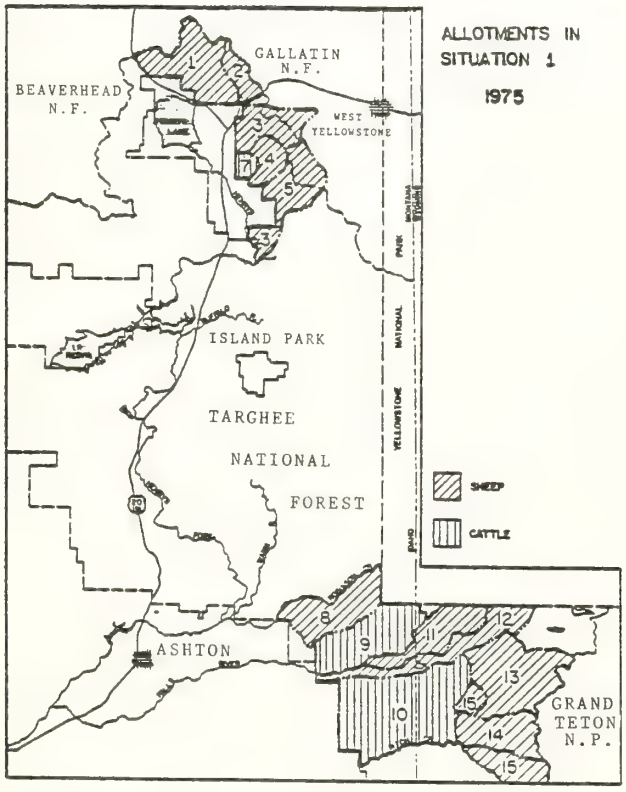


Figure 5.--Livestock allotments in use in Situation 1 habitat in 1975 (numbers refer to allotments listed in table 2; allotment number 6 is not shown).

Although some conflicts between grizzlies and cattle have occurred, the major problems have been between sheep and bears.

Table 3 shows the number of grizzly bears estimated to have been killed since 1960. To place the data in table 3 in proper perspective two factors must be considered:

1. Until August 1975, when the grizzly was declared a threatened species, a grizzly bear preying on sheep was treated the same as any other predator. Thus kills before 1975 were legal.

2. Of the eight kills estimated to have occurred since 1975, only two were actually verified.

Table 3.--Targhee National Forest estimated grizzly bear mortality associated with Situation 1 allotments[1]

Years	Sheep Allotments: Two Top/Reas Pass	Sheep Allotments: Squirrel Meadows/Boone
1960	2	
1965	1	
1966	1	
1967	1	
1968	1	
1969	2	
1970	5 (6)	2
1971	1	2
1972	2	1
1973	1	2
1974-75	2	1
1976-79		7
1980-84	0	0

[1]1960-1979 estimates by John Weaver based upon grizzly bear mortality report by Carole Jorgensen (1979); 1980-1984 compiled by authors.

In 1981, the Forest completed a biological evaluation of "Man--Grizzly Bear Conflicts Related to Sheep Grazing in Essential (Situation 1) Grizzly Bear Habitat." This document was the result of 5 years of research and subsequent alterations in the management and alignment of domestic sheep allotments. It was submitted to the Fish and Wildlife Service for formal consultation and received a no jeopardy opinion. Key provisions of the biological evaluation and resulting no jeopardy opinion are as follows:

1. The number of sheep allotments was reduced from 11 to seven. This reduction allowed the Forest and permittees to avoid historic high conflict areas; it also allowed more room to move sheep should a conflict or potential conflict occur.

2. Several allotment boundaries were changed to avoid areas of historic conflict.

3. Permittees would not use traps, snares, or poison to control black bear predation. Free-ranging black bears would not be taken except under State hunting regulations. Predator control for bears would only be done by Federal trappers.

4. Should a conflict occur or appear imminent between sheep and a grizzly bear, the sheep will be moved or, if necessary, removed from the allotment until the conflict is resolved.

5. The Forest Service would provide a full-time monitor during the sheep grazing season.

6. The permittees would cooperate in the monitoring program by reporting locations of sheep kills or other incidents related to grizzly bear conflicts.

7. Any action taken by the permittees or their agents that violated the Endangered Species Act would be grounds for canceling the permit.

8. Camps would be maintained as directed to reduce chances of attracting bears.

9. The allotment annual plan of use would designate areas to be grazed and their season of use.

In 1983, the Forest proposed and evaluated the conversion of one sheep allotment (Rock Creek) to a cattle allotment. The Forest Service consulted informally about the conversion with the Fish and Wildlife Service, which favored the proposal. The number of sheep allotments within Situation 1 habitat was subsequently further reduced to six.

The Draft Targhee Land Management Plan presently permits six domestic sheep allotments and five cattle allotments within Situation 1 habitat. This is in agreement with the previous formal consultations with the Fish and Wildlife Service.

In 1983, a radio collared female grizzly bear (known as No. 38) and her two yearling cubs found sheep grazing on the Two Top allotment. A detailed accounting of this incident has been prepared by the Forest Service (1983). When No. 38 and her two cubs began using private land and Situation 3 habitat, they were trapped and relocated into Yellowstone National Park.

Radio tracking in the fall by the Interagency Grizzly Bear Study Team indicated that they returned to their normal denning area. Using the best biological data possible, it was determined that the sow and cubs would probably return to the Two Top allotment. The Forest Service, therefore, directed the permittee to use a different allotment during the 1984 grazing season. The permittee voluntarily agreed to graze a different allotment again in 1985.

Economic conditions have not been favorable for many sheep ranchers in recent years; some have gone out of business, at least temporarily. As a result, two additional sheep allotments have been vacant in Situation 1 habitat. Table 4 and figure 6 summarize livestock grazing in Situation 1 habitat for 1984 and 1985. Compared to the level of grazing in 1975, the number of sheep allotments in use has declined by 73 percent and the number of sheep being grazed by 72 percent. The amount of cattle grazing has remained the same.

Depending primarily on the economics of sheep ranching the vacant allotments in Situation 1 habitat may be permanently closed, or suitable portions may be considered for conversion to cattle allotments. Direction in the Forest Plan specifies that permits for grazing sheep in Situation 1 grizzly bear habitat that are waived back to the government will not be reissued.

Full-time monitoring is occurring on all sheep allotments still in use within Situation 1 habitat.

At the present time, grizzly bears on the Targhee National Forest have fewer opportunities for conflicts with sheep than at any time since the Forest officially came into being.

Drafts of the Targhee's final plan and final environmental impact statement were submitted to the Fish and Wildlife Service for formal consultation. It was the opinion of the Fish and Wildlife Service that "implementation of the Proposed Targhee National Forest Plan ... is not likely to jeopardize the continued existence of the ... grizzly bear."

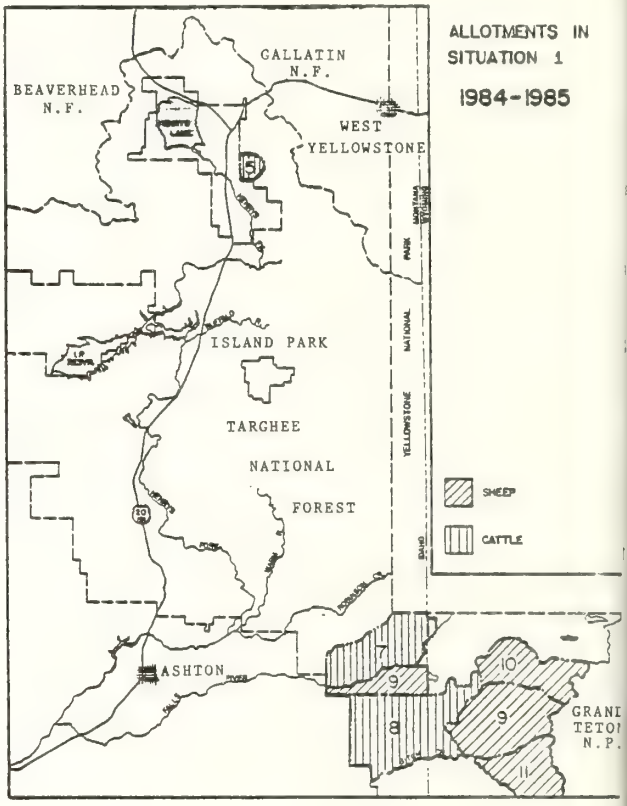


Figure 6.--Livestock allotments in use in Situation 1 habitat in 1984 and 1985 (numbers refer to allotments listed in table 4; allotmer number 4 is not shown).

Table 4.--Summary of permitted livestock grazing in Situation 1 grizzly bear habitat, 1984 and 1985

	Allotment name	Type	Permitted grazing use	In use
1.	Targhee Mountain	Sheep	1,200-ewe band	No
2.	East Targhee	Sheep	1,000-ewe band	No
3.	Two Top	Sheep	1,200-ewe band	No
4.	Garner Canyon	Cattle	26 AUM's [1]	Yes
5.	Twin Creek	Cattle	198 AUM's	Yes
6.	Rock Creek	Cattle		No
7.	Fall River Ridge	Cattle	2,420 AUM's	Yes
8.	Squirrel Meadows	Cattle	4,699 AUM's	Yes
9.	Squirrel Meadows	Sheep	1,000-ewe band	Yes
10.	South Boone	Sheep	1,000-ewe band	Yes
11.	Middle Bitch	Sheep	1,000-ewe band	Yes

Total: 3 sheep allotments in-use: 3,000 ewes
4 cattle allotments in-use: 7,343 AUM's

[1]Animal unit months.

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GRIZZLY BEARS, INSECTS, AND PEOPLE:

BEAR MANAGEMENT IN THE MCDONALD PEAK REGION, MONTANA

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ABSTRACT: Historically, grizzly bears congregate July through September on McDonald Peak in the Mission Mountains on the Flathead Indian Reservation to feed upon an aggregation of ladybird beetles (Coccinelidae) and army cutworm moths (Noctuidae). Recreational use of the McDonald Peak region has increased from essentially no use in the mid-1950's to eight to ten parties per week climbing the Peak in 1980. The Confederated Salish and Kootenai Tribal Council has closed the area to public use from mid-July to October 1 since 1981. Objectives of the closure were to provide for human safety and to protect a site critical to the Mission Mountain grizzly bear subpopulation. The closure will decrease bear exposure to people, possibly reducing the rate of habituation. Since grizzly bears must occupy the heavily populated Mission and Swan valleys in the spring and fall, the closure will allow them to remain at high elevations for a longer time where there are fewer threats to life, fewer opportunities for people-bear conflicts, and better opportunities to gain enough weight on high-protein insects to make interaction with humans later in the year less likely. Although a major concern was the public's response to closing a popular hiking area, visitor compliance was nearly complete and attitudes were positive and supportive. Furthermore, we observed 10, 11, and eight bears in 1981, 1982, and 1983. There were indications the closure aided the bear population by decreasing mortality and increasing bear use of the Peak.

INTRODUCTION

Grizzly bears (Ursus arctos horribilis) inhabit the Mission Range in western Montana. They den above 7,000 ft, spend spring in both the Mission and Swan valleys below 4,000 ft, generally summer above 7,000 ft, and spend fall in the Mission Valley (Servheen 1983; USDI, BIA 1985).

The population is declining because of high mortality from people-bear conflicts in the valleys (Claar and others in press). The Confederated Salish and Kootenai Tribes (CS & KT) and the Bureau of Indian Affairs (BIA) have an active management program to limit this mortalit and to reverse the downward population trend (CS & KT and BIA 1981). The management plan's goal is to secure and maintain a viable, self-sustaining population in critical habitat on the Flathead Indian Reservation (FIR). An important element of this plan is to protect habitat and t minimize human-bear competition. The purpose of this paper is to describe the management of a unique area in the Mission Mountains: the McDonald Peak region.

East McDonald Peak, at 9,820 ft, is the highest mountain in the Mission Range with a relief of approximately 6,600 ft in 4 airline miles (fig. 1). The Mission Range is protected by two wilderness areas: an 89,500-acre tribal wilderness area and a 73,000-acre component of the National Wilderness Preservation System (CS KT 1982). Timberline varies between 7,500 and 8,000 ft, depending upon aspect. Davis (1916), Harrison and others (1969), and Pardee (1950) provide a detailed geologic description of the Mission Mountains; Alt and Hyndman (1972) provid a more general description. Servheen (1981, 1983) and Servheen and Klaver (1983) described the grizzly bear habitat on the FIR.

BACKGROUND ON THE MCDONALD PEAK REGION

Grizzly Bears

Records of grizzly bears congregating on McDonal Peak extend for over 60 years (table 1). Although these records are not complete, they show a consistent pattern of family groups on th Peak from late July through August. Jack Romer (1982) observed "literally hundreds of grizzly bears," mainly females with young, between 1932 and 1956 in his many visits to the Peak.

Bud Cheff, Sr. (1985) observed grizzly bears on McDonald Peak from the late 1920's to the present. He mainly saw the bears in August

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A B

Figure 1.--A, McDonald Peak from U.S. Highway 93 near St. Ignatius, MT. B, Basin on McDonald Peak where the grizzly bears aggregate. Photo is taken from the observation post for censusing.

Table 1..--Historical observation on McDonald Peak

Date	Total	Number of adults	Number of young	Citation
Previous to 1924	1			Elrod (n.d. a)
Following year	7	5	2	Elrod (n.d. a)
Aug. 1924	1	1		Elrod (n.d. b)
Aug. 3, 1932	12			Chapman and others (1955)
July 26, 1946	7	2	5	Underhill and Underhill (1950)
Aug. 3, 1949	3	1	2	Wright (1982)
July 22, 1951	2	2		Wright (1982)
Sept. 19, 1952	0			Wright (1982)
Shortly after Aug. 15, 1953	4	1	3	Wright (1982)
Aug. 23, 1957	1	1		Stockstad (1959)
Approximately Aug. 15, 1965	4	2	2	Pfeiffer (1982)
Approximately Aug. 15, 1966	4	2	2	Pfeiffer (1982)
Summer 1967	1	1		Pfeiffer (1982)
Summer 1977	3	1	2	Pfeiffer (1982)

eating insects on the Peak and grazing in the surrounding meadows. The bears usually gathered in the evenings when the insects became more active. All ages and sexes were observed on McDonald Peak, but females with young were common.

There is some debate about why bears are on McDonald Peak in the summer months. Chapman and others (1955) reported that the bears were eating ladybird beetles (Hippodamia caseyi Coleoptera: Coccinellidae) and army cutworm moths (Euxoa [Chorizagrotis] auxiliaris Lepidoptera: Noctuidae). Shoemaker (Elrod n.d. b, Romer 1982; Chapman and others 1955) observed the bears consuming ladybird beetles. Chapman (Chapman and others 1955) collected 15 scats; nine consisted largely or entirely of army cutworm moths, and none contained ladybird beetles. Pfeiffer (1982) observed bears licking rocks with high magnesium chloride content. Romer (1982) believed the females also gathered to protect their young from males.

Insects

Ladybird beetles make long migrations from prairie valleys to mountaintops for hibernation (Fields and McMullen 1972; Harper and Lilly 1982). Edwards (1957) and Harper and Lilly (1982) believed that ladybird beetles hibernate on mountaintops for protection from the extreme cold of the prairies; the mountain snowpack providing insulation from the cold. Heavy mortality can occur during hibernation as masses of dead bodies may be found in summer months (Chapman 1954; Chapman and others 1955; Edwards 1957).

Aggregation sites in south-central British Columbia (Fields and McMullen 1972) were on south-facing uppermost slopes among fractured boulders covered with lichens. The beetles were in crevices between rocks. These aggregation sites became snow-free earlier in the spring than did other parts of the mountain because of the south aspect, topography, and wind that created shallow snowpacks. Ladybird movements to aggregation sites began in early September and finished by mid-October; dispersal began in early June and was completed by late June. Some ladybirds were at all elevations in July and August, but the greatest densities were in the valley alfalfa fields.

These observations from south-central British Columbia generally describe the situation on McDonald Peak; however, Chapman and others (1955) reported seeing large aggregations of the beetles (5 to 10 gallons could have been collected in a day) on August 3, 1932. They speculated that these could be overwintering beetles since snow fields were still abundant.

Army cutworm moths migrate from the Great Plains in the spring to mountaintops for estivation in order to escape the high temperatures (Cook 1927; Pepper 1932; Pruess 1967; Walken 1950). The same individuals return to the plains in the fall (Pruess 1967). Before the moths migrate, their bodies are approximately 70 percent protein. When they return in the fall, the moths have gained weight as fat (Pruess 1967); so the moths are active during estivation (Chapman and others 1955; Pruess 1967; Johnson 1969). They are only sometimes diurnally active at treeline, but are usually found near alpine meadows in dry places under rocks during the day (Pruess 1967).

Army cutworms are not a serious pest in the Mission Valley (Bratton 1985). The closest area with a large army cutworm infestation is the Three Forks, MT, region (Jensen 1985), approximately 160 airline miles from the Mission Valley. Army cutworm moths apparently are able to migrate 300 miles between spring and summer (Pruess 1967).

People

Recreational use of the McDonald Peak Basin has increased substantially since 1950. Stockstad (1959) described Cliff Lake, located at the base of McDonald Peak, as having no signs of human use. He had "never seen an area that was as free from the mark of man."

By 1978, the situation at Cliff Lake had drastically changed (Rockwell and others 1978). The lake had 17 campsites, 15 of which could accommodate one or two tents, had one or two fire rings, and had lost a moderate amount of vegetative ground cover. The other two sites had moderate loss of vegetative ground cover. The Cliff Lake and McDonald Peak area received 1,400 visitor-days over a 136-day season in 1979, as recorded at the Glacier Lake trailhead (CS & KT 1985). These data do not represent an exceptionally high level of use relative to surrounding areas, but do indicate a strong trend of increasing use.

McDonald Peak, besides being the highest peak in the range, is also the most scenic. It is within 4 miles of a major north-south highway, U.S. 93. Easily seen from this popular route to Glacier National Park, it is within 40 miles of Missoula, population 33,000 and 70 miles from Kalispell, population 11,000. The Peak is easily climbed from several faces without technical equipment or skill. The chance of observing grizzly bears on the Peak has been another major attraction (Underhill and Underhill 1950).

People have seldom had confrontations with grizzly bears on the Peak, although observations of bears were common. The basin on McDonald Peak where the bears aggregate is also the best route for climbing the mountain. McDonald Peak and the surrounding basins are above timberline so few escape routes exist if someone surprises a bear. Before 1980, we had no formal reporting system for these close encounters of the ursid kind, but we know of at least one report. A hiker played dead after observing a bear at close range. The

bear smelled the hiker and left; neither bear nor hiker was injured. We have received only two reports of bear-human confrontations since 1980, both in 1981.

MANAGEMENT OF THE MCDONALD PEAK AREA

Management direction was being developed for the McDonald Peak area between 1980 and 1982. The Council of CS & KT was developing a wilderness management plan for the area (CS & KT 1982) and they approved the FIR Grizzly Bear Management Plan (CS & KT and BIA 1981) in June 1981. One provision in the grizzly bear plan allowed the Chief of Tribal Fish and Game Conservation Department to close areas when grizzly bears remain in a specific backcountry area.

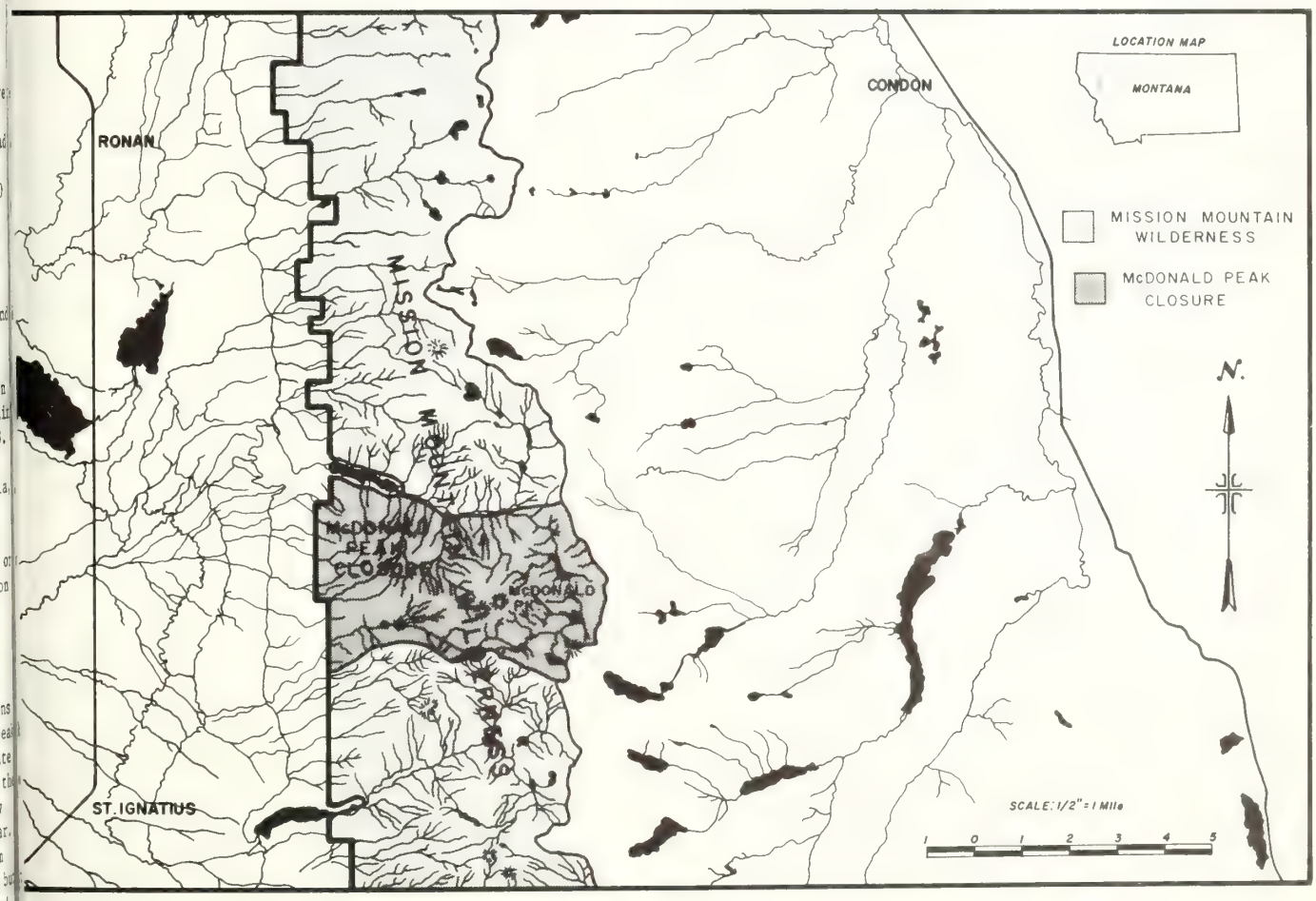
Several events led to the decision to close an area surrounding McDonald Peak in 1981. During a routine radio-tracking flight on July 22, 1981, an unmarked female with cubs was observed on McDonald Peak; subsequent flights revealed an additional female but with older young. We received two reports of parties of climbers having encounters with grizzly bears on the Peak.

The Tribal Council decided that the region surrounding McDonald Peak should be closed to all public use on July 28, 1981. The proposed date to reopen the area was originally September 15, and later extended to October 1, since grizzly bears were still on the Peak in mid-September.

The closed area included all lands surrounding McDonald Peak that grizzly bears might use in their normal movement patterns (fig. 2). Closure of this area allows the bears to remain undisturbed and without contact with people. Additionally, its topographical boundaries make it easily defined to the public.

Objectives of this closure were to ensure human safety and to protect a critical site for grizzly bears.

These objectives made the closure different from those of other agencies. Historically, closures were short term and primarily to protect human safety. This 10,000-acre closure was to allow bears an extended time free from human disturbance. We expected the closure to last a minimum of 6 weeks and were attempting to slow the rate of habituation.



igure 2.--Mission and Swan valleys showing the McDonald Peak Grizzly Bear Closure and the CS & KT ission Mountain Wilderness.

Closing the area to human use would allow the bears to feed undisturbed. Few bears are killed at high elevations in the Mission Range (Claar and others in press) so the longer the bears remain undisturbed on the Peak, rather than being forced to move to the Mission Valley, the safer they would be. Because their stay in the Mission Valley below 4,000 ft would be shorter, the Valley's residents would also benefit. Finally, if the bears were well fed on insects throughout the summer, we hoped they would be less tempted to depredate livestock or become involved in other causes of bear-human conflict.

We did not want bears to become habituated to people, especially since they must live close to residences in the spring and fall (Servheen 1983). Residents of the Mission Valley have been intolerant of bears that were not wary of people. McArthur Jope (1982), Jope (1985), and McCullough (1982) believe that frequent and innocuous contacts with people resulted in habituation.

Habituation toward people of female grizzly bears with young has not been observed and probably occurs at a slower rate than for the rest of the grizzly bear population (McArthur Jope 1982, 1983). Because females with young were an important segment of the bear aggregation, we did not want females teaching their young aggression toward people. This was especially important to us, because many of these bears would be living next to homes a few weeks later (Servheen 1983). Additionally, females with young are more likely than other bears to avoid areas with high human use (McArthur Jope 1983). McArthur Jope (1982) recommended prohibiting human use of areas used by females with young.

To inform the public of the closure, trailheads leading to the closed area were posted. Some access roads were temporarily closed with a cable. Adjacent U.S. Department of Agriculture, Forest Service, ranger districts on the Flathead and Lolo National Forests notified their visitors of the closure at ranger stations and in the backcountry. They posted explanatory signs at trailheads on their land leading into the closed area.

CS & KT and BIA staff patrolled both back and front country locations. Management staff did not enter the closed area, but monitored the area from the perimeter. The primary purpose of these patrols was to inform and educate visitors, but personnel had enforcement capabilities as well. Public reaction was favorable. Visitors were happy to learn of the closure because they did not want to camp or hike with a high density of grizzly bears, and they wanted to protect and restore the bear population. The only negative comments were that we should not be specific when describing the bears' location because of concern about poaching and other sources of disturbance. The only group we discovered intentionally violating the closure was a Boy Scout troop from Missoula.

A major concern was the public response to closing a popular hiking area. We prepared two formal press releases and gave numerous interviews to radio stations and newspapers. These interviews gave us a chance to explain the need to exclude people from the area and helped to secure public support. To further enlist the support of backcountry users, we spoke to local wilderness groups, mountaineers, backcountry horsemen, and other users between the end of the 1981 closure and start of the 1982 closure. To date, we have not received any complaints about the closure of McDonald Peak during the height of the climbing season. We included a section on the closure in the FIR grizzly bear management slide program, which is presented to a variety of audiences about twice a month during the year.

The procedures established in 1981 have been used in subsequent years. The day the closure starts depends upon when the bears arrive on the Peak. We use fixed-wing aircraft to determine presence or absence of bears. Flights begin in mid-July and continue as needed. The closure began on July 21, July 27, and August 3, 1982, 1983, and 1984, respectively. The closure was lifted on October 1 each year.

MONITORING THE GRIZZLY BEAR POPULATION

The aggregation of grizzly bears on McDonald Peak appeared to be a unique opportunity to monitor the population in the Mission Range. We used fixed- and rotor-wing aircraft and ground observations, and the latter were the most useful. We established a base camp approximately 1 airline mile from the bears on a ridge to the southwest. Bears were observed with binoculars and spotting scopes early in the morning until they bedded for the day and again in the late afternoon until dark. Personnel generally spent 3 or 4 days per week in the camp for 2 separate weeks. We recorded age (adult, subadult, yearling, or cub), coat characteristics, and group size of all bears observed. These notes helped to distinguish individuals. The best time to count the bears on McDonald Peak was mid-August. We summarized observations by the census period, by the week, and by the field season. The total number of bears using the Peak in a field season was estimated using the descriptions of bears, the total maximum count, and completing the age/sex categories.

The number of bears observed was lower when aircraft were used. Helicopters gave the poorest results. We watched a female with cubs hide when she first heard the helicoptor. This is comparable to Ballard and others' (1982) observation that females with young were more secretive than other bears. Fewer bears were observed from fixed-wing aircraft than the ground observations; however, we occasionally had good results. We plan to use the technique of Maggnuson and others (1978) of simultaneously observing bears from the ground and fixed-wing aircraft to achieve a better population estimate

The number of bears observed was 10, 11, and eight in 1981, 1982, and 1983, respectively (table 2). Servheen (1983) estimated the grizzly bear population in the Mission Range to be 25. The sex/age composition is comparable to the historical accounts. We hope these observations will allow us to estimate recruitment of cubs at 6 months, survivorship of cubs to yearlings, and population trend. The number of cubs explains the variation between years. Apparently, no cubs or yearlings died.

An adult female with yearlings radio-tracked in 1979 provided data on the movement patterns of bears using McDonald Peak. She was on the Peak between July 11 and September 13. Of the 42 relocations between July 1 and September 20, 50 percent occurred on the mountain. Between July 1 and August 10 she spent 32 percent (n=22) of the time on the Peak, with several abrupt movements between the mountain top and the valley bottom. Between August 11 and 31, all her relocations (n=13) were on McDonald Peak. Between September 1 and 20, 12 percent (n=8) were on the Peak. She may have left McDonald Peak in early September because of the changing nutritive value of the vegetation and insect migration. The trip to McDonald Peak on September 13 may have been to feed on returning ladybird beetles.

The observations of grizzly bears on McDonald Peak in recent years are consistent with this pattern. Bears were on the Peak for 44, 54, and 39 days in 1981, 1982, and 1983, respectively. The greatest number of bears observed from the ground camp occurred on approximately August 20. Of the 12 bears for which it was possible to determine length of stay, 10 remained on the Peak for more than 20 days.

We are using these data as part of the overall data base on grizzly bears. We will not depend solely on this trend information until the technique is validated, because it may be biased in some fashion or reflect the status of only a portion of the population. We need to determine from how large an area the bears are attracted to the Peak, the percentage of the population that uses McDonald Peak, when and if males stop using the Peak, and how consistently individuals use the Peak.

Of special concern is the monitoring of a population in its best habitat. Kruck (1977) found that a mountain goat (Oreamnos americanus) population was declining, but the trend count from the best winter range was stable because the goats moved into this area when vacancies occurred. If grizzly bear monitoring followed this pattern, the population could collapse in the Mission Mountains even though numbers observed in prime habitat would remain stable until it was too late to correct the situation. Other sources of information we use to monitor the population are kill statistics, movement of radio-collared bears, trapping success, and direct observation in other areas of the range.

If this technique proves useful, it may be applied to other areas of the Northern Continental Divide Grizzly Bear Ecosystem. Places like Kintla Peak (Kendall 1985) and Bear Valley (McArthur Jope 1982) in Glacier National Park, and Scapegoat Mountain (Craighead and others 1982), for example, have aggregations of grizzly bears eating insects, roots, or berries. These areas and probably many more may be used to monitor grizzly bear populations. Care must be taken to ensure that the animals using these concentration areas are representative of the total population.

EVALUATION AND CONCLUSIONS

McDonald Peak is mainly used by females with their young. Radio-tracking of three male grizzly bears from July through August showed that they used lower elevation habitat (USDI, BIA 1985). Females may use the Peak to protect their young from males, which use different areas. Russell and others (1979) found that females with young were mainly on upper slopes and in hanging valleys, where escape routes were plentiful. They believe that this habitat use was to avoid males which used the valley bottoms or lower slopes.

Table 2.--Number and classification of grizzly bears observed on McDonald Peak, 1981-1983

Year	Total	Adults[1]	Female adults	Cubs	Yearlings	Subadults[2]
1981	10	2	2	2	2	2
1982	11		3	3	2	3
1983	8	2	1		3	2

[1]Adults of unknown sex.
[2]Ages 2-5 years.

Insect ecology needs to be better understood. It is necessary to know where the insects come from and their population dynamics in order to understand yearly changes in grizzly bear use of the mountain and their food habits. Additionally, army cutworms are serious agricultural pests and heavily sprayed with insecticides; grizzly bears may be bioconcentrating these organochlorides. Ladybirds are reported to taste bad to predators (Borror and others 1976) and thus may explain why they are not always found in scats. We need to determine the food value of the ladybirds and army cutworm adults to better understand their value to the bears. Pfeiffer's (1982) observation that the basin where the grizzly bears are found has areas high in magnesium chloride may explain why the army cutworm moths and ladybird beetles migrate there.

It is too early to determine the success of the McDonald Peak management program. There are, however, indications it may be working. Nine grizzly bears died in the 4 years before the closure, 1977-1980; only three died in the 4 years following the McDonald Peak closure (Claar and others in press; USDI, BIA 1985). A female grizzly bear that did not use the insect concentration when radio-tracked in 1978 and 1979 was observed on the mountain in 1982 and spent 3 weeks on the Peak in 1983. Visitors' compliance was nearly complete, and they supported the closure. These results and those from areas which subsequently adopted this plan provide some encouragement that this management action is working.

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Session VI—Cumulative Effects

Chaired by:

James Claar, Supervisory Wildlife Biologist, Bureau of Indian Affairs, Flathead Agency, Pablo, MT

CUMULATIVE EFFECTS ANALYSIS: ORIGINS, ACCEPTANCE, AND VALUE TO GRIZZLY BEAR MANAGEMENT

Alan G. Christensen

ABSTRACT: The cumulative effects analysis process developed on the Kootenai National Forest was born of need generated by proposals for access and activity in critical grizzly bear habitat. It has been applied to the analysis of extremely controversial projects involving hard rock mineral exploration and has been the focus of conflict between rights granted in the 1872 Mining Law and responsibilities of Federal agencies under the Endangered Species Act of 1973. Despite suits and threats of suits from developmental and environmental interests, the process has been accepted and utilized by Forest Service land managers. This paper outlines the process and explores the application of cumulative effects analysis to Forest activities over the past 3 years and how that application has assisted in making sensitive land management decisions. It also suggests that analysis of land management activities has been permanently altered by applying a cumulative effects perspective.

INTRODUCTION

Cumulative effects analysis has received a great deal of attention in recent years. As applied on the Kootenai National Forest, the process assesses how human activities affect the environment in space and time and how those changes may influence grizzly bears.

The Kootenai process (Christensen and Madel 1982) involves the field identification of 13 distinct habitat components, the mapping of the extent and location of those components on topographical maps, and the development of "activity" overlays on Mylar. The process is somewhat labor-intensive and the process requires users to have a detailed knowledge of the geographical area and accurate information about the nature and timing of the activities proposed. Each working base map covers approximately 200 mi^2. Supporting data sheets detail the quantity, seasonal importance, and identity of the grizzly bear habitat components known to occur within the area. Mylar overlays depict road access and influence zones, land management activities, recreational and mineral activities, and other information determined to influence grizzly bear habitat.

The resulting combination provides managers with detailed grizzly habitat information in the form of base maps. These maps enable them to graphically display and measure how known activities will affect grizzly habitat in terms of space, time, food, and denning habitat. The process tracks and displays activities that potentially affect grizzly habitat by directly reducing available space and foods or by influencing the time and manner in which other related activities can be accomplished. Thus, although each activity taken independently may be relatively innocuous, the synergistic effect of several management actions may be significant. Ecologically and philosophically, cumulative effects analysis provides an opportunity to examine the whole picture while meeting day-to-day management needs.

BACKGROUND

Grizzly bears were declared a threatened species in 1975, at which time large corporate mineral interests had already conducted extensive prospecting and claiming of suspected copper-silver deposits in the Cabinet Mountains in northwestern Montana. Grizzly bears and the copper/silver-bearing Revett Formation inevitably were drawn together when the Kootenai National Forest delineated essential habitat in late 1977. Contained within the boundary of the essential habitat were claims and exploratory drill holes that had given evidence of important copper-silver deposits.

In the late 1970's, there was a paucity of information on grizzly bears or their habitat in the Cabinet Mountains. The Forest funded a study (Erickson 1978) to ascertain whether grizzlies still existed in the Cabinets and to provide some general information on habitat. About the same time, the Section 7 consultation requirements of the Endangered Species Act were implemented. As of May 1979, the Forest had never formally consulted on grizzly bear issues, so procedures and mechanisms were untested. At

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that time, a proposal for a helicopter-supported exploratory drill operation in essential grizzly habitat inside the Cabinet Wilderness was submitted and analyzed. With little data on the grizzly bear or its habitat and no established procedure, the biological evaluation became a review of existing literature and a list of assumptions on how they related to the situation.

In 1980, the problem became considerably more complex when a proposal was submitted for a 3-year multihole exploratory drilling program in grizzly habitat. The biological evaluation focused on available foods, seasons of use, and assumptions about bear response to mechanized equipment. The evaluators were frustrated because, although other activities were already affecting grizzly bear habitat in and adjacent to the Cabinet Wilderness, there was no recognized procedure for effectively dealing with them or weighing their effects. The exploratory drilling permit was granted and appealed, and after denial of the appeal, a lawsuit was filed in Washington, DC by a coalition of environmental groups. The subsequent judgment supported the issuance of a permit to drill, but it became clear from this experience that a better method of analyzing activities in grizzly habitat was sorely needed.

That same year, Kootenai National Forest personnel began to describe and map grizzly bear habitat components. These food and denning components became the basic descriptions of grizzly habitat and ultimately provided the basis for development of a cumulative effects process.

In 1981, the Flathead National Forest, Glacier View District, published a cumulative effects process that consisted of displaying activities on a series of maps and overlays and coordinating activity schedules to minimize overlap and conflict. The process failed to quantify impacts, identify baseline habitat needs for grizzly bears, or draw conclusions on the condition of habitat before or after analysis. Despite its limitations, it was a valuable procedural step.

By 1982, the Kootenai National Forest had produced a cumulative effects analysis process (Christensen and Madel 1982) which built on the Flathead document. In contrast to the Flathead document, however, the Kootenai cumulative effects analysis process identifies and quantifies food and denning components, space, and the availability of habitat to grizzlies at any time.

DISCUSSION

Immediately upon completion, the cumulative effects process was applied to ongoing activities in the Cabinet Mountains. An area of approximately 500,000 acres was divided into eight distinct bear units for analysis. This area required 15 project maps and data on 72 drainages, the result of 2 years of field work. Simultaneously, the developers of the process put emphasis into explaining the process to the general public, various organizations and clubs, State and Federal agencies with grizzly management responsibilities, and the Kootenai National Forest management team. They also produced a brief video presentation for ranger districts and other Forests. The process met with enthusiastic and nearly universal acceptance, mainly because the process is a simple assemblage of relationships and not a complex model, even though it includes considerable detail. Nearly everyone could understand the basic elements involved (food and habitat security), was aware of the underlying ecological principles, and could comprehend the tangible array of information on maps and overlays. This accessibility facilitated its acceptance.

A National Forest is made up of separate districts, all of which have individual rangers who exercise a great deal of autonomy. Management style, personal philosophy, and work ethic influence how each ranger operates the district. In dealing with a resource which cuts across district boundaries and for which no universally accepted methodology of management exists, the differences between how districts deal with that resource can be significant, controversial, and disruptive. Because grizzly bears have a large home range size and the mobility to quickly move across administrative boundaries, proper management of their habitat necessitates cooperation among all involved. Before the development of cumulative effects analysis, individual districts and Forests had evolved independent methods for dealing with grizzly bears. One ranger might favor road management; another would not implement road closures. Adjacent districts used different coordination techniques, different contract language, and different management limitations. All of this was confusing to contractors and the general public and raised questions about which course of action was correct.

Coordination of in-house activities in the Forest Service is complex and makes it difficult to predict habitat conditions over time. Yet in-house activities are directed by various laws, policies, and regulations and are reviewed by the interdisciplinary process. When unscheduled demands from other agencies or individuals are superimposed on in-house activities, resource management becomes extremely complex, particularly for a species as mobile and controversial as grizzly bears.

Hard rock mineral exploration in the Cabinet Mountains is such an unscheduled demand. Based on rights granted by the Mining Law of 1872, individuals can claim, prospect, explore, and develop mineral deposits on public lands, even within Wilderness areas. Major mineral activity proposals cause a ripple effect through all Forest programs and create an air of unpredictability, which raises questions about the certainty of previously scheduled in-house

activities. It was into such an environment that the cumulative effects analysis process was initiated on the Kootenai National Forest in 1982. At that time circumstances surrounding a major hard rock mineral exploration effort were directly affecting two ranger districts with scheduled annual timber harvests of over 40 million board feet and established public use of the south half of the Cabinet Mountains. The situation had been tested in Federal court, was the subject of frequent consultation between U.S. Department of the Interior, Fish and Wildlife Service, and Kootenai National Forest personnel, and was closely scrutinized by many special interest groups.

APPLICATIONS

Public acceptance and feedback about the cumulative effects analysis process contributed significantly to management's acceptance and willingness to apply it. Early confidence and interagency support were important.

Application of the process forced the first complete inventory of all known planned activities within a given area on the Forest. Much like the process used on the Flathead, all activities were identified and maps and schedules were prepared. Estimates of public recreational activities within the area were based on historical use patterns. This information provided a checklist of activities over most of which the Forest Service had some discretionary control, an important point in the later identification of mitigation and compensation options.

Overlaying this information on habitat maps clearly protrayed the level of activity and how it affected grizzly bear habitat. Combining activity and habitat information permitted managers to determine for the first time what habitat was being affected, how scarce or abundant that habitat was, and what the cumulative effects of planned resource management decisions were.

The Forest Service cannot deny rights granted under the Mining Law of 1872 but can only influence how they are conducted. Therefore, in the cumulative effects perspective, statutory rights had to be accommodated; discretionary activities became the method by which space and components were freed up for compensation. With the cumulative effects process, managers could observe options and measure their effects on space and food components. The ability to quantify and weigh tradeoffs, to measure the effect of various decisions on grizzly habitat, and to observe the results enabled managers to control situations rather than react to them. Even though some options were distasteful, managers could choose a course of action with a clear idea of the tradeoffs. This capacity created high credibility for the cumulative effects process among managers. With increased confidence in the system came reassurance that administrative and litigative actions could be dealt with and that, rather than being reactive and defensive, managers were being proactive.

Not only did this confidence help managers deal with internal scheduling and decision making; it facilitated the coordination of permit requests with other activities. With the knowledge and perspective gained from cumulative effects analysis, managers were able to identify permit requirements, schedule demands, and identify the constraints necessary to protect important grizzly habitat while meeting other resource demands. Of equal importance, management could respond significantly faster once a cumulative effects analysis had been conducted. Options and constraints for that calendar year were quantified and highlighted so that new proposals could be quickly analyzed and firm responses could be made. An interesting circumstance developed when those who first applied for activity permits established a "first in time, first in right" stance. This perspective worked to the disadvantage of late applicants but did not constrain the Forest Service from providing for minerals exploration activity.

As experience with the system in land management increased, decisions were directly related to how space and food for grizzly bears would be affected, what seasons were best for activities to occur, and how close each bear unit approached threshold levels. In addition, by determining that ongoing activities were pushing the system to threshold levels, managers could foresee that additional activities would have to be rescheduled, modified, or wait until space and time became available.

Some aspects of the system had negative results. The process includes an assumed threshold that identifies the level of habitat effectiveness necessary to meet the needs of an adult female grizzly. Despite caveats about the reliability of the threshold, managers at times scheduled activities to use up all available space and time to threshold limits. At other times the threshold became a security point and managers were uncomfortable about finding conditions that were just below the quantified threshold and sought ways to get slightly above, even though biologically the changes were of no consequence. With the demands on public lands, the identification of threshold values can pose a risk in that the threshold may become the level at which a resource is managed. In that light, thresholds should be identified with caution.

As of 1985, the Kootenai will have been applying the cumulative effects analysis process to portions of the Forest for 4 consecutive years. Despite imperfections in the process and the use of extrapolated data, application of the process has substantially benefited grizzly habitat management and the process has become standard operating procedure. All districts now share a common management methodology and understand the need for shared information and tradeoffs.

Management credibility remains high, and legal action against Forest decisions has declined. Coordination with major corporate mineral interests has been simplified, and consistent use and reliance on the process has reduced the corporations' apprehension.

As a management tool, the cumulative effects analysis process on the Kootenai National Forest has been successful. As data from the ongoing Cabinets grizzly bear study are incorporated, the process will undoubtedly improve.

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CUMULATIVE EFFECTS ANALYSIS OF GRIZZLY BEAR HABITAT ON THE LEWIS AND CLARK NATIONAL FOREST

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ABSTRACT: An interagency work group derived a cumulative effects analysis process tailored to a selected bear management unit and using grizzly bear data from ongoing studies along the Rocky Mountain Front. Analysis is done by constituent element within a bear management unit, and a scoring system is used to assess each human activity's contribution to cumulative effects. Patterns of bear use (radio locations and observations gathered by Rocky Mountain Front grizzly studies) were analyzed to determine three zones of habitat effectiveness (high, moderate, low), which are used to display the results of the cumulative effects analysis. Thresholds were designated. Radiotelementry data from the bear management unit gathered subsequent to the development of this cumulative effects analysis process have tended to verify the zones of habitat effectiveness determined with this analysis process.

INTRODUCTION

The primary purpose of an interagency work group formed in 1983 was to assess cumulative effects on grizzly bears (Ursus arctos) and gray wolves (Canis lupus) in the area of a proposed exploratory natural gas well on the Lewis and Clark National Forest. The group was composed of Keith Aune and Gary Olson, Montana Department of Fish, Wildlife and Parks; Wayne Elliott and Thomas A. Day, U.S. Department of the Interior, Bureau of Land Management; and Steve Solem and Lewis Young, Lewis and Clark National Forest. The group decided to develop an analysis using grizzly bear data available for the Rocky Mountain East Front that would apply along the entire Front.

As a first step, the interagency work group reviewed the process developed and implemented by the Kootenai National Forest (Christensen 1982). They decided the East Front situation differed enough from the Kootenai to make unmodified use of the Kootenai process unfeasible. Habitat component mapping, which is key to the Kootenai process, is not yet available for the East Front, and a great deal of bear data from the Front are available from ongoing grizzly studies that began in 1977.

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Two of the basic components of the Kootenai process, however, were considered useful: the bear management units and using adult females as the key population segment.

ANALYSIS PROCESS

Bear Management Units

All occupied habitat on the Rocky Mountain East Front between U.S. Highway 2 and U.S. Highway 200 was divided into six units (called bear management units or BMU's) using the following criteria:

1. Units will be based on the amount of effective habitat necessary for a given number of adult female grizzly bears (subpopulation goal).

2. Each unit must contain all the seasonally required habitats and space (constituent elements) in sufficient quantity to meet the subpopulation goal.

3. Spring constituent elements should be similar within each unit.

4. Each unit should fit general movement patterns observed for radio-collared grizzly bears. (The existing data bases fit each unit.)

5. Each unit should have a similar mountain orientation and topography that influences forage richness, movements, and travel corridors.

Resulting BMU's range in size from approximately 250 to 420 mi^2 (650 to 1 090 km^2).

Studies by the Interagency Wildlife Monitoring/Evaluation Program indicate that in the core study area the grizzly population is healthy, stable, and at or near carrying capacity considering the limitations on capacity by current land uses and human activities (Aune and Stivers 1982; Aune and Stivers 1983; Aune 1983). Seven adult females occupy the core study area (Aune 1983), which is nearly the same in size and location as two BMU's combined (Birch-Teton and Teton-Sun River). The density of adult females in these two BMU's, then, is 1/97.4 mi^2 (1/252 km^2).

Extrapolating this density to the other BMU's provides an estimate of biological potential for adult females:

Badger-Two Medicine	4.1
North Fork Sun River	2.6
South Fork Sun-Beaver-Willow	4.3
Dearborn-Elk-Falls	3.0

Constituent Element Mapping

Constituent element maps of the Lewis and Clark National Forest were developed in cooperation with Keith Aune, Montana Department of Fish, Wildlife and Parks, by mapping landtypes (Holdorf 1981) that had been used by radio-collared grizzlies (Aune and Stivers 1982). Landtypes used for denning were at elevations above 6400 ft (1 952 m) in accordance with observed den site elevations (Aune and Stivers 1983).

Baseline Activities

Various human activities take place annually and form a baseline from which to evaluate cumulative effects. Each activity and the area it influences directly or indirectly (influence zone) is mapped (fig. 1). Influence zones are based on research data from East Front grizzly studies, literature, and professional opinions of bear biologists. Baseline activity definitions are in the appendix.

An influence zone of 1 km (0.6 mi) was mapped around each road open to four-wheeled vehicles based on East Front grizzly studies (Aune and Stivers 1983). An influence zone of 1 km (0.6 mi) was also mapped around oil and gas drill site locations (Harding and Nagy 1980).

Trails, snowmobile routes, timber activities, campgrounds, trailheads, and administrative sites all were mapped with 0.5 mi (0.8 km) influence zones. Chester (1976) recorded the flight of bears whenever humans were detected at distances up to 0.5 mi (0.8 km), and humans are involved in all of the previously mentioned activities. Grazing, private land, and hunting activities were mapped only in the area involved.

The matrix used to derive the effect scores (table 1) displays the baseline activities on the left side. We recognized that several of the baseline activity categories should eventually be refined by further subdividing some of the categories (for example, dividing roads into high or low use), but initially the activities were kept as simple as possible.

Scoring System

The cumulative effects analysis is done by BMU by constituent element; a scoring system is used to assess each activity's contribution to cumulative effects. Each activity is evaluated for six potential effects and displayed in a matrix format (table 1).

Potential effects of human activities are displaye along the top of table 1. The work group assigned the numbers 1 to 6 to the effects based on the group's collective opinion as to the relative seve ity of each effect, with 6 being the most severe. Permanent loss of habitat was judged more severe i the long run than the death of a bear. Lack of management potential was judged equal to reduced forage because having the ability to manage can strongly influence the other effects. Reduced cov was judged less severe than reduced forage because bears will feed in areas well away from cover if they are not disturbed. Displacement was judged least severe of the six effects because the basic assumption was that bears have an area of equally effective habitat into which they can move. For each activity, an X is placed in the appropriate column if the effect is applicable. The numbers applicable for each checked effect are added to derive the effect score for each activity.

Activity duration is a factor in describing the impact; therefore, the duration (in months) of eac activity is multiplied by the effect score (from table 1) to arrive at an impact score (table 2). The effect of overlapping human activities is addi tive; therefore, the impact scores associated with human activities (as mapped in fig. 1) are totaled to derive a cumulative effects score (fig. 2).

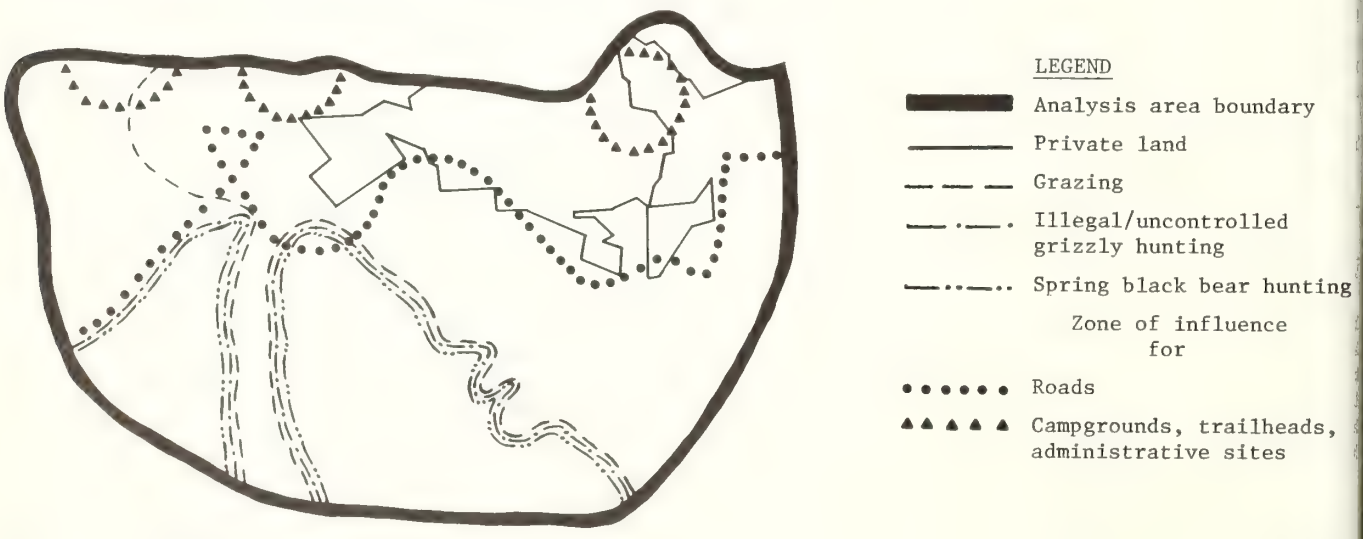


Figure 1.--Example of human activities in spring.

Table 1.--Effect scores by activity[1]

Activities	Effects: Permanent loss of habitat (6)	Direct mortality (5)	Lack of management potential (4)	Reduction in forage (4)	Reduction in cover (3)	Displacement (1)	Effect score
Hunting							
Illegal/uncontrolled		X	X			X	10
Legal		X				X	6
Grazing		X		X	X	X	13
Roads	X	X		X	X	X	19
Private land	X	X	X	X	X	X	23
Timber				X	X	X	8
Trails						X	1
Summer homes, administrative sites, campgrounds, trailheads	X	X		X	X	X	19
Snowmobiling					X	X	4

[1]See text for explanation of scoring.

Visual Display

A color scheme facilitates the visual display of the cumulative effects analysis. Three color zones are used to subjectively describe habitat effectiveness.

Green.--High habitat effectiveness. Human activities are at a level that generally allows grizzlies to make full use of the habitat.

Yellow.--Moderate habitat effectiveness. Human activities are at a level that reduces habitat effectiveness, but grizzlies are able to make some use of the habitat. The cumulative effects level is nearing the red zone.

Red.--Low habitat effectiveness. Human activities are at a level that permits only limited grizzly use of the habitat; however, red zones are still occupied habitat. A red zone generally indicates a "may effect" situation, which is defined as one having an apparent direct or indirect effect on the conservation and recovery of a listed species. The determination of "no effect" or "may effect" is an integral part of the consultation process between federal agencies and the U.S. Fish and Wildlife Service under the Endangered Species Act.

Table 2.--Activity impact scores for concentrated use spring range

Activity	Effect score	X	Duration	=	Impact score
Illegal/uncontrolled grizzly hunting	10		3		30
Legal black bear hunting	6		3		18
Grazing on forest	13		1		13
Grazing off forest	13		3		39
Private land	23		3		69
Roads	19		3		57
Campgrounds, trailheads, admin. sites					
Summit area	19		2		38
Cow camp, Hwy.2 trailhead, Palookaville, Badger	19		1		19

Threshold Determination

Once the cumulative effects scores were mapped, the work group was faced with determining a threshold value for each of the habitat effectiveness (color) zones. Because of the data available from East Front studies, the group decided to use, to the extent possible, grizzly use patterns to indicate what areas were providing habitat.

For spring and summer/fall constituent elements, they compared the cumulative effects score map with grizzly observation and radio-relocation data collected from 1977 to 1983 by East Front grizzly studies in the Badger-Two Medicine BMU. A breakpoint between red and the other zones was determined first. If a pattern of use appeared in an area, it was judged to be providing effective habitat. A cumulative effect score that was representative of the break between those areas with a use pattern and those areas with little or no use was selected as the threshold between the yellow and red zones. The threshold between the green and yellow zones was determined in a similar manner by comparing use patterns with the cumulative effects scores and selecting a score that represented the break between areas of moderate and higher use. For the denning constituent element, thresholds were based

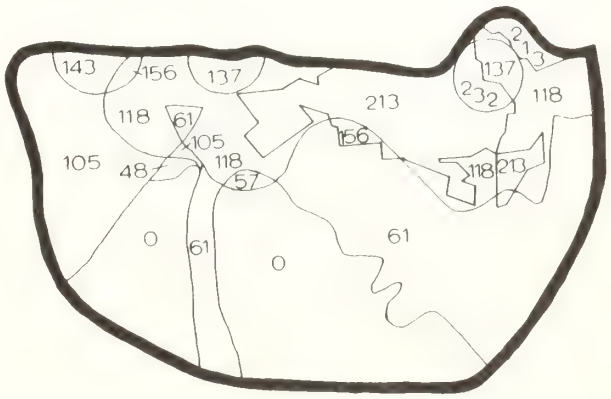


Figure 2.--Example of cumulative effect scores for spring.

on information derived from grizzly denning data from East Front studies (Aune and Stivers 1983; Schallenberger and Jonkel 1979) and other literature (Harding and Nagy 1980) that indicate bears are sensitive to disturbance both during den selection and while in the den and thus select remote, inaccessible denning sites.

Next it was necessary to determine the amount of area required by constituent element to maintain a target population. The best data on seasonal home ranges and densities are available from the core study area of the East Front grizzly study. Spring home range sizes are available for adult female grizzlies on the core study area, but concentrated use spring range has not been mapped off the National Forest. Therefore, a density figure for concentrated use spring range cannot be calculated yet. Density is believed to be the appropriate measure to use since it accounts for the overlap of home ranges.

Considering the foregoing, minimum space requirements on the spring consitituent element were derived as follows: The density of adult female grizzlies on the core study BMU's (where the population appears to be healthy, stable, and at or near carrying capacity) is 1 per 97.4 mi^2 (1/252 km^2). When extrapolated to the Badger-Two Medicine BMU (398.1 mi^2, or 1 031 km^2), this density results in a potential population of 4.1 adult females. If those 4.1 females were using the 133 mi^2 (345 km^2) of concentrated use spring range at the same time, the resulting density would be one adult female per 32.4 mi^2 (84 km^2), an area that is then used as the minimum space required to maintain each adult female grizzly on concentrated use spring range.

In the summer/fall constituent element, 97.4 mi^2 (252 km^2) is used as the minimum space required to maintain each adult female. This is the density of adult females from the core study area BMU's, and the entire area within all BMU's is considered summer/fall habitat.

Determination of Effect

The analysis process allows the determination of "may effect" in either of two ways. First, if the cumulative effects of baseline plus proposed activities significantly decrease habitat effectiveness (that is, color zones change from green to yellow to red), then a "may effect" situation exists. When an activity is proposed, an effect score and impact score are determined as in tables 1 and 2. The impact score is added to the cumulative effects score from baseline activities, and the new cumulative effects score is compared to the thresholds for color zones to see if the proposed activity changes the color zone. The analysis process also permits the evaluation of baseline activities to determine what options are available in the form of adjusting baseline activities to accommodate proposed activities when in combination they exceed threshold values for cumulative effects

The second way relates to population and space more directly. Derivation of the minimum space requirements for a target population of adult females has been described under Threshold Determination. If the cumulative effects analysis determines that the amount of green and yellow color zones is at or less than the minimum required to maintain a target population, then a "may effect" situation exists.

APPLICATION, VERIFICATION, AND FUTURE CONSIDERATIONS

This cumulative effects analysis process was applied to a controversial proposal to drill an exploratory natural gas well on the Lewis and Clark National Forest in the South Fork Two Medicine River drainage. The process was accepted by the U.S. Fish and Wildlife Service as an acceptable method of analying cumulative effects. Radiotelemetry data gathered subsequent to the development of this analysis process have tended to verify the zones of habitat effectiveness determined with this analysis process.

At the time this process was developed and applied the work group realized that further refinement was possible and desirable and that the greatest refinement would result from applying the process to the BMU's with the greatest amount of bear data (Birch-Teton and Teton-Sun River BMU's). Nevertheless, the Lewis and Clark National Forest has ceased work on this analysis process and is pursuing the latest generation of cumulative effects analysis (cartographic modeling) for several reasons. It quickly became obvious that the manual system of overlay analysis was both labor and time intensive and did not easily lend itself to rapid updating of data or rapid analysis of proposed activities and alternatives. The Forest Service is then pursuing an interagency effort to develop a cumulative effects model for all ecosystems that uses the basic model developed for the Greater Yellowstone Ecosystem (GYE). This model includes a habitat quality factor that was absent from the Lewis and Clark analysis process, and the GYE model is designed for computer application through cartographic modeling.

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APPENDIX: BASELINE ACTIVITY DEFINITIONS

Legal hunting.--Hunting for game species in accordance with Montana Department of Fish, Wildlife and Parks regulations. Mortality results from hunting and some displacement occurs due to bears avoiding hunters (Aune 1983).

Illegal/uncontrolled hunting.--Illegal hunting is that which occurs inside the National Forest boundary but is not in accordance with Montana Department of Fish, Wildlife and Parks regulations. Uncontrolled hunting is that which takes place on the Blackfeet Indian Reservation. Effects are similar to legal hunting, but the potential for management is lower.

Grazing.--Includes all aspects associated with livestock allotments of domestic sheep and cattle or horses. Several mortalities have been associated with livestock grazing along the Front (Aune and Stivers 1983). Livestock grazing, especially in riparian/aspen areas, reduces available forage and cover (Jonkel 1980), and some bears appear to be displaced by grazing and associated activities like herding or salting (Aune 1983).

Roads.--All travelways open to the use of four-wheeled vehicles are included. Roads cause physical loss of habitat as well as reduce the availability of forage and cover because bears tend to avoid roads (Aune and Stivers 1982; Elgmork 1978). Road access increases the vulnerability of bears to direct mortality.

Private land.--For the Badger-Two Medicine BMU, this includes all the Blackfeet Indian Reservation and private lands within the National Forest boundary. State and Federal agencies concerned with grizzly bear management have little or no control over bear management, especially habitat management, on private lands. Direct mortalities often result from conflicts on private lands. Permanent habitat losses occur through building construction and conversion of good habitats like riparian areas to hayfields or other crops. Grazing and crop production reduce forage and cover, and human activities can displace bears.

Timber.--All aspects of timber management and harvest are included (for example, timber sales, post and pole sales, planting, thinning, firewood gathering). The roads associated with most timber activities are rated separately. Forage and cover are reduced by timber activities, at least for the short term, and displacement occurs as well (Zager 1980).

Trails.--Those travelways open to travel by foot, horse, or motor vehicles less than 40 inches (102 cm) wide. Only those trails receiving higher levels of use are included. The habitat effectiveness of an area traversed by a trail is reduced when some level of activity (use) is reached because of displacement. Chester (1976) documented bear displacement along trails due to encounters with people; Schallenberger and Jonkel (1979) discuss some relationships between trails and grizzlies.

Summer homes, administrative sites, campgrounds, trailheads.--Because of human occupation, the potential for direct mortality exists. The structures and facilities required for this category of activity permanently destroy habitat. Forage and cover may be reduced because of recreational livestock grazing around these sites as well as being unavailable due to displacement from human activities around these sites. Schallenberger and Jonkel (1979) discuss the relationships of bears to these sites.

Snowmobiling.--The use of over-the-snow machines has the potential to displace animals and reduce the effectiveness of cover along traveled routes.

DERIVATION OF HABITAT COMPONENT VALUES FOR THE YELLOWSTONE GRIZZLY BEAR

David J. Mattson, Richard R. Knight, and Bonnie M. Blanchard

ABSTRACT: Methodology is described by which values, as coefficients, were derived for grizzly bear habitat components in the greater Yellowstone area. The specific algorithm incorporates measures of diet item value, relative frequency of diet item consumption, preference for diet item consumption, diversity of feeding activity or opportunity, and seasonal adjustment in calculation of each habitat component coefficient. Methodology is also described by which number of feed sites can be estimated and further allocated among habitat components for diet items that are grazed and whose use is not discernible by feed site analysis.

INTRODUCTION

Quantitative habitat evaluation, risk analysis (Salwasser and others, in press), and, most recently, cumulative effects analysis (Christensen 1982; Weaver and others this volume) are being used for increasingly sophisticated grizzly bear habitat management. All these techniques require some numeric evaluation of map units, whether individual habitat components or extensive bear management units.

Other studies in the Northern Rocky Mountains have derived numeric values for grizzly bear habitat components (Mealey and others 1977; Christensen 1982; Craighead and others 1982; Mace 1984), and all have based their numeric evaluations primarily on known vegetal diet items in various map units, typically habitat components. Random or stratified-random sampling was used to enumerate representative diet items. In two studies (Craighead and others 1982; Mace 1984), representation of diet items was weighted by the relative food value or preference assigned to them.

Additional research has explored grizzly bear habitat preference (Zager 1980; Aune and Stivers 1981; Servheen 1983; Knight and others 1984) but has not transformed this information into relative numeric habitat valuation. In any case, studies employing use-availability analyses (Neu and others 1974; Marcum and Loftsgaarden 1980) generate empirical results that are often difficult to interpret and that may have limited extrapolability (Knight and others 1984).

The Interagency Grizzly Bear Study Team (IGBST) also developed a method for deriving habitat component values, one that is conceptually more sophisticated then previous approaches. The methodology used an extensive data base derived from scat and community site analysis collected over a 7-year period, 1977-83, in association with radio-telemetry sampling of grizzly bear habitat use. The Team also used digitized map data for Yellowstone National Park provided by D. Despain. This approach was conceptual and thus allowed flexibility and extrapolability in using derived coefficients. The methodology was also compatible with the cumulative effects analysis model developed for the greater Yellowstone area (Weaver and others this volume). This paper presents the logic and details of the IGBST approach.

METHODS

Food habit and habitat data used for generating habitat component coefficients were collected by the IGBST as part of followup to aerial radio-telemetry location of collared grizzly bears. Scats were collected for analysis and comprehensive field forms were completed; habitat type, cover type, and feeding activity were identified. Mapping of the greater Yellowstone area is being completed using standard habitat and cover types also employed in IGBST analysis of grizzly habita use. Blanchard (1985) discusses in more detail methods pertinent to collecting data used for generating habitat component coefficients. Mattson and Despain (1985) discuss methods pertinent to the mapping and digitizing of cover and habitat types in Yellowstone National Park.

RESULTS

Our methodology for deriving habitat component coefficients delineated a variety of spatial and temporal strata. In applying the technique, however, we were conceptually limited regarding habitat components, that is, relatively homogeneous, abstract topographic-vegetation

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habitat units that recur over the landscape and are identifiable by specific criteria. We used as habitat components, and thus calculated values on a seasonal basis (spring, summer, and fall) for, individual forest and nonforest habitat and community types (Pfister and others 1977; Mueggler and Stewart 1980; Gregory 1983; Steele and others 1983; Mattson 1984).

The Team used four data sets in model development and calculations: (1) frequency and volume scat data stratified by taxonomically identifiable diet items and by date; (2) community site analyses stratified by feeding activity types, habitat components, and date; (3) unit area food values, stratified by date, associated with diet items extracted by characteristic feeding activities; and (4) summary statistics for habitat component area in Yellowstone National Park. Unit area food values (data set 3 above) integrated measures of per-bite energetic efficiency, exclusivity of use, nutritive value, landscape search efficiency, and year-to-year fluctuation in use/availability (Mattson and others in preparation).

In calculating unit area habitat component value (UHV'_{jk}), we integrated five basic factors (fig. 1): (1) unit area food value (UFV_{ik}) associated with each feeding activity/feed site type, by season; (2) proportionate representation of feeding activity types (X_{ijk}) relative to all community site analyses recorded, including those without evident feeding activity, by habitat component and season; (3) preference or relative feed site density (APF_{ijk}) recorded for each habitat component, by feeding activity type and season; (4) diversity of recorded feeding activity (DI_{jk}), by habitat component and season; and (5) an adjustment factor (F_k) reflecting seasonally disparate numbers of utilized habitat components:

$$UHV'_{jk} = \left(\left(\sum_{j=1} UFV_{ik} * X_{ijk} * APF_{ijk}\right) * DI_{jk} * F_k\right)/UHV_{jk\ max} \quad (1)$$

Value attributable to a habitat component was thus partitioned among these various factors.

Each feed site or feeding activity type was imparted the value (UFV_{ik}) of the associated extracted diet item. This imparted value was further weighted by relative preference or feed site density (APF_{ijk}) recorded for each feeding activity in each habitat component. Feed sites of the same type were accorded equal value but occurred, because of grizzly preference or site availability, with varying unit area frequency (density) in habitat components. Therefore, UFV_{ik} was multiplicatively weighted by APF_{ijk} to adjust for difference feed site type densities.

Feed site density or preference (PF_{ijk}) was the quotient, by component, of proportionate feed site distribution among habitat components (Y_{ijk}) divided by either proportionate area availability of each component (P_j) or proportionate distribution of all community site analyses, whether feed site or not, among components (Y_{jk}). Use of P_j or Y_{jk} depended on philosophical or conceptual point of view as well as scale of reference. PF_{ijk} was adjusted by natural logarithmic transformations to account for sensitivity of the quotient to small per-type sample size and representation. Natural log transformations were applied for $Y_{jk} \leq 0.25$, untransformed quotients used for $Y_{jk} > 0.75$, and an average of log transformed and untransformed values employed for $Y_{jk} > 0.25$ and ≤ 0.75. APF_{jk} resulted from scaling PF_{ijk} for each feeding activity type from 0.00 to 1.00 among habitat components.

The contribution of each feeding activity type to total habitat component value was a linear function of the proportionate representation of each feeding activity (X_{ijk}), as feed sites, in each habitat component. Thus, the product of $UFV_{ik} * APF_{ijk}$ for each feeding activity type was further adjusted by multiplication of X_{ijk}. A preliminary score (PS_{jk}) for each habitat component resulted from summation of the products for each feeding activity:

$$PS_{jk} = \sum_{i=1} (UFV_{ik} * X_{ijk} * APF_{ijk}) \quad (2)$$

PS_{jk} ranged in value from 0.00 to 1.00. At this point in the calculations no differentiation was made between components with only one potential feeding activity and other components with several.

Greater diversity of feeding activity or opportunity was logically considered to enhance the value of a habitat component. The probability of feeding opportunity, within an analysis time frame, was considered to be greater in those types with greater feed site diversity, especially given the large year-to-year fluctuations in diet item use and availability in the greater Yellowstone area (Picton and others this volume) and the correspondence of feed sites and clumped diet item populations within the matrix of a habitat component. Shannon-Weiner H' (Shannon and Weaver 1963; $H' = -\Sigma X_{ijk} \ln X_{ijk}$), constrained to minimum and maximum values of 0.333 and 1.000, was employed to approximate the effect of feeding activity/opportunity diversity (DI_{jk}) on habitat component value:

$$DI_{jk} = ((0.667/H'_{jk\ max})H'_{jk}) + 0.333 \quad (3)$$

The effect was assumed to be linear, although likely to be shown later as curvilinear, and so PS_{jk} was multiplied by DI_{jk}.

Further adjustment of calculated habitat value reflected seasonally disparate grizzly bear use of the total landscape. Greater value was assumed to be associated with components used during spring and fall when a fraction of available components provided food. This greater value was in contrast to summer, when nearly all components were available and producing some amount of food. In other words, during spring

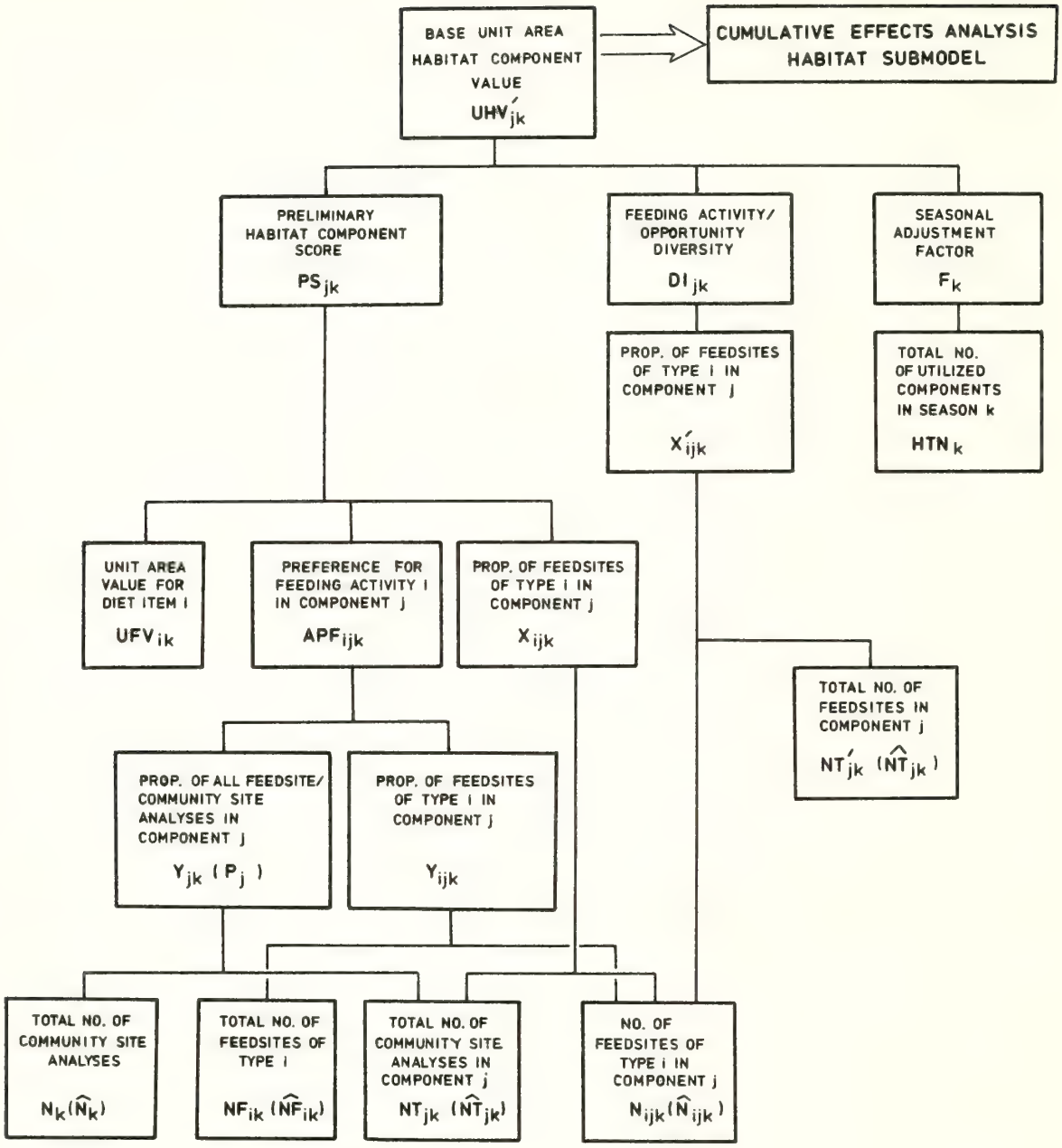


Figure 1.--Model diagram for calculation of base unit area habitat component value (UHV'_{jk}).

and, to a lesser extent, fall, landscape value (feeding activity) was concentrated in many fewer components than during summer. To facilitate comparison of habitat component seasonal values, factors (F_k) were applied to spring and fall values in inverse proportion to the number of components used. This interpretation of habitat value was considered to be sensitive to management dealing with seasonal scheduling of human activities. A habitat component used during both spring and summer and which produced cover and food of ostensibly equal value during both seasons was, by our logic, actually more valuable or sensitive to disturbance during spring.

Each component unit area value (UHV_{jk}) was divided by maximum UHV_{jk} to scale values of the resulting UHV'_{jk} from 0.000 to 1.000. Scaled unit area coefficients (UHV'_{jk}) applied to habitat components in the Yellowstone ecosystem (sic) cumulative effects analysis process were standardized to maximum UHV_{jk} across all strata, by season and by presence of ungulate concentrations (Weaver and others this volume).

One difficulty was encountered in calculating unit area habitat component values (UHV'_{jk}). Feed site data were essentially nonexistent for grazed diet items; with the exception of thistle *(Cirsium scariosum)*, most grizzly bear grazing activity was not distinguishable from that of ungulates. Bear use of grazed diet items was, however, adequately documented by scat analysis, as was grizzly bear habitat occupancy by community site analyses associated with radiotelemetry sampling. From these data, grizzly bear grazing activity, as number of feed sites, could be estimated for each habitat component.

Two steps were required before numbers of feed sites could be estimated for each grazed diet item in each habitat component. First, a general relationship had to be developed between number of feed sites and unit scat frequency for those diet items extracted by bears in a manner (that is, by digging or some definitive manipulation) that allowed confident discernment at feed site-community site analyses. This relationship approached being a constant, $\hat{NFFQ}$. Scat frequency, by diet item, was used to estimate $\hat{NFFQ}$ because frequency was theorized to better correspond with feed site numbers. Scat volume reflected per-feed site diet item density as much or more than number of feed sites.

Using scat frequency data (FQS_{ik}) and estimated per-unit scat frequency feed site number ($\hat{NFFQ}$), a total feed site number was calculated ($\hat{NF}_{ik}$) for each grazed diet item. The next step required allocation of these feed sites among available habitat components.

Allocation of feed sites ($\hat{NF}_{ik}$) among habitat components was based on allocation scores (AS_{ijk}) calculated for each component for each grazed diet item by season (fig. 2);

$$\hat{N}_{ijk} = \hat{NF}_{ik} \left(AS_{ijk} / \sum_{j=1} AS_{ijk}\right) \quad (4)$$

Allocation scores were, in turn, based on three factors: (1) the correspondence, or fidelity, between ranked diet item use frequency distribution, as estimated by scat analysis, and ranked habitat component use frequency distribution, as estimated by community site analysis, by month (FIK_{ijk}); (2) the total number of community site analyses recorded for each habitat component (NT'_{jk}); and (3) the mean abundance of diet items in each habitat component (FQ_{ij}), as estimated by community site analyses:

$$AS_{ijk} = FQ'_{ij} * NT'_{jk} * AFID_{ijk} \quad (5)$$

Relative number of community site analyses by component (NT'_{jk}), scaled to values ranging from 0.00 to 1.00, and the correspondingly scaled mean abundance of diet item by component (FQ_{ij}), when multiplied together, yielded a probabalistic measure of feeding activity occurrence by component and diet item. Investigation of habitat component use associated with reliably discerned feeding activity indicated, however, that component use was not a strict function of diet item abundance and frequency of habitat component occupancy. Area-wide and temporal patterns of food use and availability to a significant extent subsumed use of individual diet items in individual components. This other source of variation was more or less accounted for by assessing the fidelity in frequency distribution across months for habitat component and diet item use ($AFID_{ijk}$).

$AFID_{ijk}$ resulted from inverting and rescaling a measure of fidelity ($AFID_{ijk}$):

$$AFID_{ijk} = 1 - (FID_{ijk}/NM_{ik} - 1) \quad (6)$$

FID_{ijk} was the average difference between ranked use frequency, by month, for each component and diet item during a specified time frame (NM_{ik}):

$$FID_{ijk} = \sum_{m=1} \left[RS_{imk} - R_{jmk}\right])/NM_{ik} \quad (7)$$

As correspondence or fidelity in distribution of component and diet item was increased, FID_{ijk} linearly decreased.

DISCUSSION

We consider a habitat component to be any relatively homogeneous, abstract topographic-vegetation habitat unit that recurs over the landscape and is identifiable by specific criteria. The methodology described here for deriving habitat value is appropriate only when used to evaluate habitat components. This approach is conceptually invalid if applied to specific microsites or large-scale mapped areas such as grizzly bear management units or subunits. Weaver and others (this volume) describe how values generated by this methodology are incorporated in calculations of habitat value for large areas. An additional set of determinant factors are operable when extensive mapped areas are evaluated.

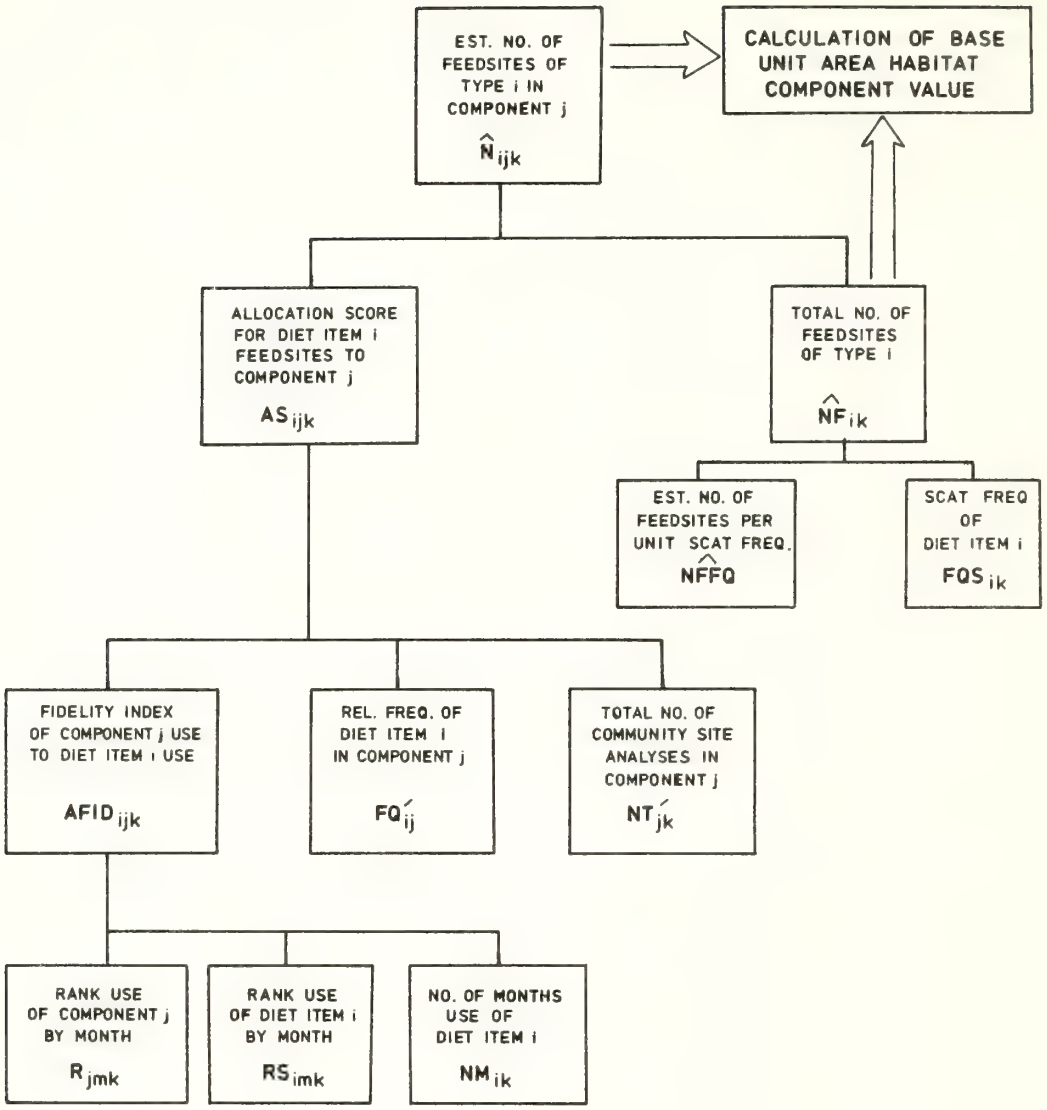


Figure 2.--Model diagram for estimation and allocation of feed sites ($\hat{N}_{ijk}$) among habitat components.

Our approach to generating base unit area habitat component value has several advantages. Foremost is the inherent flexibility lacking in results of use-availability analysis or empirical modeling. Using the methodology described in this paper, new habitat component values can be generated as components are redefined, data sets enlarged or restructured, analysis time frames readjusted, and foraging environments simulated (Picton and others this volume). This can all be achieved by manipulating the data sets integral to calculation of habitat values. A conceptual modeling approach also helps clarify relationships and contributing factors as well as identify research areas where data are scanty or totally lacking.

Most relationships in this model are linear; however, researchers have elucidated as many nonlinear as linear ecologic relationships (Hall and Day 1977). So, in the absence of more specific research and data, we have assumed linearity while expecting to later revise relationships in the model. In any case, the methodology described in this paper is faithful to our current state of knowledge concerning the grizzly bear and uses the most extensive data base available for any grizzly bear population. Logically derived and conceptually sound habitat component values will be available to ongoing management.

Wherever possible, habitat component coefficients generated by this methodology have been and will be tested. In general, despite its limitations and requirements for astute interpretation, use-availability analysis is the best standard by which conceptually derived unit area component values are judged. Results of such analyses in the greater Yellowstone area (Knight and others 1984) substantially conform with coefficients produced by this methodology.

Another possible test of these coefficients is as integral parts of the Yellowstone cumulative effects model (Weaver and others this volume) used for generating habitat effectiveness and mortality risk in specific large-scale management areas. Density of radio-telemetry fixes accumulated over our 10-year study period could be used as a quasilegitimate independent test of management area habitat effectiveness values and, more indirectly, of the habitat component coefficients integral to calculation of the effectiveness values.

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APPENDIX

Variables: calculation of unit area habitat value.

N_{ijk} = number of community site analyses of feeding activity type i in habitat type j during season k.

NT_{jk} = total number of community site analyses in habitat type j during season k.

NT'_{jk} = total number of community site analyses with recorded feeding activity in habitat type j during season k.

NF_{ik} = total number of community site analyses of feeding activity type i during season k.

N_k = total number of community site analyses during season k.

P_j = proportionate area of habitat type j.

HTN_k = number of habitat components utilized by grizzly bear during season k.

UFV_{ik} = unit area food value of diem item i associated with feeding activity type i.

$$X_{ijk} = N_{ijk}/NT_{jk}$$

$$X_{ijk} = N_{ijk}/NT'_{jk}$$

$$Y_{ijk} = N_{ijk}/NF_{ik}$$

$$Y_{jk} = NT_{jk}/N_k$$

$$H'_{jk} = \sum_{i=1} X'_{ijk} \ln X'_{ijk}$$

$$DI_{jk} = ((0.667/H'_{jk\,max})H'_{jk}) + 0.333$$

$$PF_{ijk} = -\ln(Y_{ijk}/Y_{jk});^{a}$$

$$(-\ln (Y_{ijk}/Y_{jk}) + (Y_{ijk}/Y_{jk}))/2;^{b}$$

$$Y_{ijk}/Y_{jk}{}^{c}$$

$$APF_{ijk} = PF_{ijk}/PF_{jk\,max}$$

$$F_k = HTN_{max}/HTN_k$$

$$PS_{ijk} = \sum_{j=1} UFV_{ik} * X_{ijk} * APF_{ijk}$$

$$UHV'_{jk} = ((\sum_{j=1} UFV_{ik} * X_{ijk} * APF_{ijk}) * DI_{jk} * F_k)/UHV_{jk\,max}$$

Variables: allocation of estimated number of feed sites among habitat components.

FQS_{ik} = scat frequency of diet item i during season k.

NM_{ik} = number of months during which scat frequency of diet item i was recorded during season k.

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[a] If $Y_{jk} \leq 0.25$.

[b] If $Y_{jk} > 0.25$ and ≤ 0.75.

[c] If $Y_{jk} > 0.75$.

P_j can substitute for Y_{jk} in all calculations of PF_{ijk}.

R_{jmk} = relative rank of month m, by number of community site analyses (total) in type j during season k.

RS_{imk} = relative rank of month m, by relative scat volume of diet item i during season k.

N_{jk} = total number of community site analyses in type j during season k.

FQ_{ij} = relative frequency of diet item i in plots of habitat component type j.

$\hat{NFFQ}$ = estimated number of feed sites recorded by radio relocation community site analysis per unit of relative frequency for any diet item i in scats.

$$\hat{NF}_{ik} = \hat{NFFQ} * FQS_{ik}$$

$$FID_{ijk} = \left(\sum_{m=1} \left[RS_{imk} - R_{jmk} \right] \right) / NM_{ik}$$

$$AFID_{ijk} = 1 - (FID_{ijk}/NM_{ik} - 1)$$

$$FQ'_{ij} = FQ_{ij}/FQ_{ij\ max}$$

$$NT'_{jk} = NT_{jk}/NT_{jk\ max}$$

$$AS_{ijk} = FQ'_{ij} * NT'_{jk} * AFID_{ijk}$$

$$\hat{N}_{ijk} = \hat{NF}_{ik} \left(AS_{ijk} / \sum_{j=1} AS_{ijk} \right)$$

HABITAT TYPE AND COVER TYPE AS A BASE FOR GRIZZLY BEAR HABITAT MAPPING AND EVALUATION

Don G. Despain

ABSTRACT: Habitat type is a widely used classification system that indicates site potential. The system is based on the assumption that site characteristics are integrated by the plants growing on the site. Thus, plants can be used to rapidly assess site potential. One parameter that is not addressed by the system is successional stage, or time since last disturbance. Cover type in forested communities is a simple classification of age classes that can be combined with habitat type to provide this information. If both habitat type and cover type are known for a site, it is possible to predict a large suite of site parameters that are critical for grizzly bear habitat evaluation, such as the probability of finding bear foods, year-to-year variability in site conditions, and site productivity. This information, in a computerized geographic information system, provides excellent spatial evaluation possibilities.

The method of habitat evaluation presented here has a large number of classes and provides much finer resolution than those used in other Rocky Mountain ecosystems, where only a few very broad classes are mapped and used in the evaluation process.

INTRODUCTION

Plant communities are a significant variable in the grizzly bear survival equation because grizzly bears obtain their food and cover from plants both directly and indirectly. Some plant communities provide abundant grizzly bear food and cover; others produce little. The ability to stratify this heterogeneity is therefore essential to an assessment of the effects of human activities on the grizzly bear environment.

Most studies relating grizzly bears to habitat in the Northern Rocky Mountain region have used a system developed in northwestern Montana (Zager and others 1983; Servheen 1981). That system stratifies the vegetation into 20 or fewer broad classes and emphasizes nonforested vegetation and various disturbance communities. Forested communities are treated simply as timber or as two or three classes of timber with various tree densities; however, in the Yellowstone ecosystem, some forested communities are quite important to the grizzly bear, especially whitebark pine (Pinus albicaulis) stands.

The habitat type system provides a good method of stratifying the physical environment and therefore the productivity of forested and nonforested sites (Daubenmire 1968). Unsworth (1984) and Young (1984), however, related habitat type to black bear activity and concluded that habitat type was not useful because there was no classification of nonforested types in their area, and most timbered sites were in a seral stage not addressed by the habitat type system. If, however, both habitat type and successional stage of the stands in an area are known, it should be possible to infer related information about the sites. This would allow rapid assessment of large areas and still give good resolution.

HABITAT TYPES

Many factors determine the growing conditions of a site and thus the plant species present. Some of these are easily measured, and some are not. Because we may not be aware of some important factors, direct measurement of all factors influencing a site is impractical, if not impossible.

All factors influencing a site are integrated by plants on that site; therefore, the plant community on a site is a good indirect indication of site conditions. This integration by the plants is the basis of the habitat type classification system developed more than 30 years ago by Daubenmire (1952). Since that time, it has been refined and applied to a large portion of the Rocky Mountain forests (Pfister and others 1977) and some nonforest vegetation (Mueggler and Stewart 1978; Hironaka and others 1983; Mattson 1984).

Inferences about site potential or ability to produce certain plant communities, as well as biomass production potential, can be made if the habitat type is known. Habitat types have been used to describe potential tree reproduction on logging sites (Pfister 1972), the amount of lumber to expect from a logging sale (Stage 1973), and the distribution of bird species (Weaver 1985).

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With habitat types, the landscape can be classified into discrete units of similar potential. These units can be mapped and the geographical relationships determined. Within the limits of precision of the classification and the mapping efforts, the potential of a very large area can be ascertained.

Although the habitat type system is based on climax or near climax communities, we can properly classify younger stands by observing the species in the understory and forest floor and by comparing them with older communities on similar sites. Further studies can be made to describe the various plant communities of each successional stage (see Arno 1982).

COVER TYPES

Some important characteristics of the existing plant community are determined by the time elapsed since last disturbance (succession). In forested communities this is usually expressed by the size and species of trees on a site.

Succession is a continuous process, but it can be divided into classes such as early, mid, and late stages. Adding recently disturbed and climax classes provides five easily recognizable and ecologically meaningful classes (Despain 1977). In the greater Yellowstone area, forested stands are dominated by relatively few species. Lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), whitebark pine, or a combination of Engelman spruce (*Picea engelmannii*), and subalpine fir (*Abies lasiocarpa*) are the most common stand dominants, but limber pine (*Pinus flexilis*) and aspen (*Populus tremuloides*) are also present and locally important. Each of these can provide both climax and successional stands depending on site conditions.

Dividing these dominants into successional stages produces 25 major cover types. These types are shown in the following list and described in more detail along with a few minor types in Mattson and Despain (1985). These classes are called cover types, indicating a classification based only on tree cover. All stands can be placed into both cover type and habitat type classifications.

Type Cover	Description
LPO	Recently burned or harvested stands dominated by lodgepole pine.
LP1	Even-aged, usually dense stand of lodgepole pine.
LP2	Mature stand of lodgepole pine.
LP3	Overmature stand of lodgepole pine.
LP	Climax stand of lodgepole pine.
DFO	Recently burned or harvested stands dominated by Douglas-fir.
DF1	Even-aged, usually dense stand of Douglas-fir.
DF2	Mature stand of Douglas-fir.
DF3	Overmature stand of Douglas-fir with spruce and fir in the understory.
DF	Climax stand of Douglas-fir.
SFO	Recently burned or harvested stands dominated by spruce and fir.
SF1	Even-aged, usually dense stand of spruce and fir, usually in cool, wet environments.
SF	Climax stand of spruce and fir.
WBO	Recently burned or harvested stands dominated by whitebark pine.
WB1	Even-aged, usually dense stand of whitebark pine.
WB2	Mature stand of whitebark pine.
WB3	Overmature stand of whitebark pine.
WB	Climax stand of whitebark pine.
ASPO	Recently burned or harvested stands dominated by aspen.
ASP1	Even-aged, usually dense stand of aspen.
ASP2	Mature stand of aspen.
ASP3	Overmature stand of aspen with conifer understory.
ASP	Climax stand of aspen.
L13	Overmature stand of limber pine with codominants and understory of other conifers.
L1	Climax stand of limber pine.

Grassland and shrubland habitat types occur across the landscape but at a different scale of resolution than forest types. A map of grassland habitat types would have a much higher polygon density than a forest map simply because microsite differences are more influential on the smaller statured individuals of the grassland. The need for rapid assessability and the constraints of computer memory size made it necessary to group nonforested habitat types into larger, more encompassing units. These were separated into grasslands, herblands, and shrublands, then subdivided into dry, moist, and wet types (see Mattson and Despain 1985 for full descriptions).

Disturbance and succession also occur in non-forested areas but, aside from grazing, most of the disturbances are limited. Pocket gophers are probably the most significant disturbance in grasslands and shrublands of the Yellowstone ecosystem. Gophers cause site disturbance themselves, and further disturbance results when grizzly bears dig for this important food source. These small disturbed areas are not easily distinguished on air photos.

Grazing occurs over large areas, but it is closely monitored and regulated and the pressure remains fairly constant; thus plant communities remain fairly stable. Considering all these factors, it was not deemed necessary to map differences in successional stages of the nonforested area.

The capacity of the different habitat classes to provide grizzly bear food and cover must be determined before this system can be used to assess the value of the area to these large omnivores. This has been done for the Yellowstone ecosystem and is reported by Mattson elsewhere in this volume. A value to the grizzly bear has been derived for each of the habitat type/cover type combinations. This value, when multiplied by the acres of each type, summed across all the types in an area, and modified by other values stemming from landscape relationships, gives the potential vegetational value of that area to the bear (Weaver and others this proceedings).

COMPONENT MAPPING

Previous studies in the Yellowstone ecosystem have provided a good information base for this area. Habitat types have been described for both forested and nonforested vegetation (Pfister and others 1977; Steele and others 1983; Cooper 1975; Mueggler and Stewart 1978; Hironaka and others 1983; Mattson 1984).

Mapping is quickly accomplished in several steps (Mattson and Despain 1985). Air photos are scanned stereoscopically and both nonforest and forest stands are delineated and given a temporary designation. The major tree species in the Yellowstone ecosystem are readily discernible on air photos, and different age classes are fairly easy to distinguish. This makes stand delineation fairly easy, but habitat type identification from air photos is more difficult. Representative variations in the delineated stands are selected from air photos and then examined on the ground to determine habitat and cover type. These observations are then extrapolated to neighboring stands and air photos. Very large areas can thus be efficiently mapped, and the result is a detailed map of habitat value.

These maps are then digitized and can be used in computerized geographic information systems to analyze, plan, and assess alternatives.

Both habitat type and cover type have been mapped in Yellowstone National Park. Mapping of adjacent Forest Service land by habitat type and cover type is estimated to be 50 to 70 percent complete.

SUMMARY

Grizzly bears are biological organisms that depen on biological products for survival. This statem of the obvious must be kept clearly in mind when assessing the ability of a given piece of landsca to support grizzly bears or evaluating the effect of human activity on the grizzly bear population. Variation is an almost universal characteristic o biological systems. The variation inherent in individual organisms is compounded by the variation encompassed by a population. This means th there are few absolutes in the relationships of bears to their environments. Habitat types in conjunction with cover types provide a small-scal model of this variation on which to base habitat assessment for a very large area.

There are several advantages to using habitat type/cover type as the base map. Many areas have already been mapped by habitat type for timber purposes, reducing the need for field work. Becau cover types can be reliably assessed from air phot we can obtain more detailed maps with higher resolution and, more importantly, we can use this base map for other species by simply determining the value of the vegetation types to that species and reanalyzing the habitat using those values.

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A CUMULATIVE EFFECTS MODEL FOR GRIZZLY BEAR MANAGEMENT IN THE YELLOWSTONE ECOSYSTEM

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ABSTRACT: Cumulative effects may be defined as the combined effect upon a species and its habitat resulting from multiple land uses over space and time. A Cumulative Effects Model (CEM) has been designed to (1) quantify individual and collective effects of land uses and activities in space and through time and (2) provide managers an analytic tool for evaluating alternative decisions relative to grizzly bear recovery goals and objectives. The CEM is composed of three submodels: habitat, displacement, and mortality. The habitat and displacement submodels determine the habitat effectiveness value of an area while the mortality submodel portrays mortality risks. The submodels integrate basic variables that are significant and subject to management. The habitat submodel incorporates four variables: (1) food and thermal cover, (2) habitat diversity, (3) seasonal equity, and (4) denning suitability. These variables combined indicate the year-round habitat quality of an area. The displacement submodel includes four variables of human activity: (1) location relative to hiding cover, (2) type (motorized or nonmotorized), (3) nature (linear, point, or dispersed), and (4) intensity (high or low use, day or overnight use). Displacement is characterized by a coefficient of disturbance and by an associated zone of influence. The mortality submodel incorporates four variables of human activity: (1) location relative to habitat quality, (2) nature, (3) intensity and sanitation, and (4) firearms. By integrating the submodels, the CEM provides two basic outputs: habitat effectiveness value and mortality risk index. Once thresholds appropriate for grizzly bear recovery are established for habitat effectiveness and mortality risk, managers can manipulate the numerous variables and analyze the competitive and cumulative effects of various land uses through computer simulations.

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INTRODUCTION

The Endangered Species Act necessitates that the cumulative effects of land uses and management activities upon a listed species be evaluated as part of the biological assessment process. Cumulative effects can be defined as the combined effect upon a species or its habitat caused by the activity or program at hand, as well as other reasonably foreseeable events that are likely to have similar effects upon that species or its habitat. Cumulative effects can result from individually minor but collectively significant events taking place over time.

In January 1984, the Yellowstone Ecosystem Management Subcommittee of the Interagency Grizzly Bear Committee identified the need to develop a cumulative effects assessment process for the ecosystem. The charge developed by the Subcommittee was: Develop methodology to quantitatively and qualitatively assess the cumulative effects of human activity on grizzly bear habitat, habitat use, and mortality in the Yellowstone Ecosystem. A task team of representatives from USDA Forest Service, Yellowstone National Park, and the Interagency Grizzly Bear Study Team was assigned the charge.

Because a myriad of demands has been placed on public and private lands within the Yellowstone Ecosystem, cumulative effects analysis has become an integral part of biological evaluations being prepared in occupied grizzly bear habitat. Moreover, the cumulative effects process can and should be used as an effective tool in proactive management of grizzly bear habitat.

APPROACH

Early in the cumulative effects process it became apparent that computer implementation would be necessary. The process therefore was modeled for computer implementation and is now referred to as the Cumulative Effects Model (CEM).

Design

The CEM is designed to (1) quantify individual and collective effects of land uses and activities in space and through time and (2) provide managers with an analytic tool for evaluating alternative decisions relative to grizzly bear recovery goals and objectives.

The CEM is composed of three submodels: habitat, displacement, and mortality (fig. 1). The habitat and displacement submodels determine the habitat effectiveness value of an area while the mortality submodel determines the mortality risks. The submodels integrate basic variables that can be significant and subject to management.

The habitat submodel incorporates four variables: (1) food and thermal cover, (2) habitat diversity, (3) seasonal equity, and (4) denning suitability. These basic variables combined indicate the year-long habitat quality of an area (see Habitat Submodel section for details).

The displacement submodel includes four variables of human activity: (1) type of activity (motorized, nonmotorized, or explosive); (2) nature of activity (linear, point, or dispersed); (3) length of activity (diurnal or 24-hour); and (4) disturbance intensity (high or low). Displacement is characterized by a coefficient of disturbance and by an associated zone of influence (see Displacement Submodel section for details). The displacement submodel is directly linked to the habitat submodel through the food/cover variable.

The mortality submodel incorporates five basic variables regarding human activity: (1) habitat quality, (2) nature of activity (point, linear, or dispersed), (3) intensity of use, (4) availability of attractants, and (5) presence of firearms. The relative risk of mortality can be compared among activities (see Mortality Submodel section for details). The mortality submodel is indirectly linked to the habitat submodel through habitat quality and to the displacement submodel through the nature and intensity of human activity.

By integrating the submodels, the CEM provides two basic outputs: habitat effectiveness value and mortality risk index.

Development

Development of the CEM requires two basic steps: deriving and mapping the habitat components, and categorizing and mapping the land uses and activities.

A series of digitized base maps displaying habitat/cover types for forested habitat components, nonforested habitat components, ungulate seasonal ranges and trout spawning

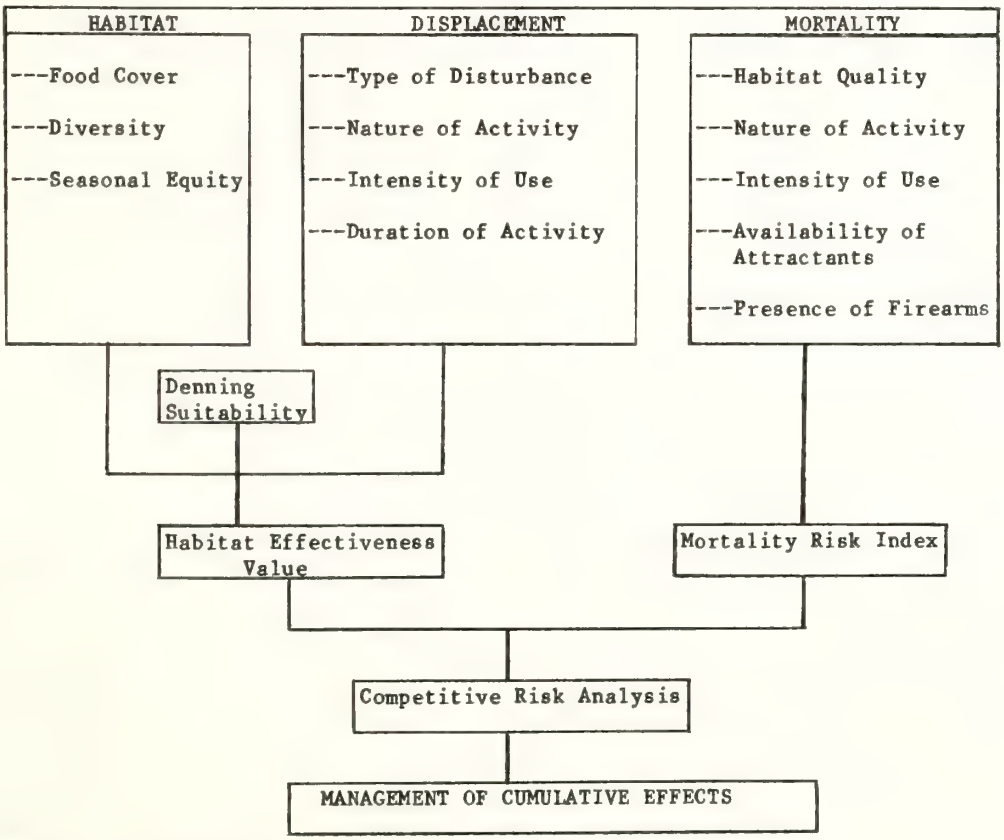


Figure 1.--A cumulative effects model for grizzly bear management in the Yellowstone ecosystem.

streams to a 5-acre resolution are generated. Both existing and potential habitat values for unique cells (polygons on the final composite map) are generated by season and stored in a computer file.

A series of digitized overlay maps showing location and nature/type of existing land uses and a file of associated coefficients for displacement and mortality are generated. The independent and combined effects upon habitat effectiveness value and mortality risk index are generated by month and stored in a computer file.

Once thresholds appropriate for grizzly bear recovery are established for the two outputs, managers can manipulate the numerous variables and analyze the competitive and cumulative risks of various land uses through computer simulations.

Delineation of Grizzly Bear Management Units

To deal with an ecosystem as large as Yellowstone, it was necessary to divide the area into smaller units to: (1) assess existing and proposed activities without having the effects diluted by consideration of too large an area, (2) closely match individual grizzly bear use patterns and habitat ecology, and (3) prioritize areas where management would require a cumulative effects analysis.

Bear management units (BMU's) were delineated using grizzly bear radio location data and topographic features. The entire area within currently designated occupied grizzly bear habitat was stratified into bear management units.

Initially, areas were delineated that had a substantial number of radio locations during 0, 1, 2, or 3 "active" seasons. Active seasons were considered to be spring (March through May), summer (June through August), and fall (September through November). Areas of extensive and contiguous substantial three-season use as well as areas without substantial use during any season were identified.

All areas with extensive and contiguous three-season use serve as a core for a bear management unit. Prominent topographic features between adjacent core areas with three-season use serve as unit boundaries. Where an area with "nonuse" or one- to two-season use adjoins one with three-season use, a prominent topographic feature closest in proximity to the area with three-season use serves as a boundary.

As a consequence, some BMU's contain extensive areas of known substantial three-season bear use (Madison, Washburn, Lamar/Slough, Crandall/Sunlight, Firehole/Hayden, Pelican/Clear, and Two Ocean/Lake). Other units are characterized by virtually no bear use (Boulder, Teton, Plateau, and Henry's Lake). These minimal-use units all occur around the periphery of occupied grizzly habitat. Other units (Gallatin, Hellroaring/Bear, Shoshone, Thorofare, Bechler/Grassy Lake) have substantial bear use during only one to two seasons or have only a limited area of three-season use.

Subunit Delineation

Subunits provide further landscape resolution as well as finer attunement to grizzly bear habitat use patterns. Subunits are delineated on the basis of seasonal component representation and interspersion. An optimal subunit corresponds to a contiguous but more or less interspersed area of spring range accompanied, in fairly close proximity, by significant areas of summer and fall range. This complex is typically encompassed by a major drainage and portions of intervening ridges. On the other hand, some subunits are distinguished (as are some units) by a uniform lack of high-value seasonal components or by the presence of high-value feeding opportunity during only one or two seasons. In the latter case, the one or two seasonal components are too far distant from other seasonal components for a substantial number of bears to efficiently integrate them in yearly ranges.

A subunit corresponds to the optimal scale for incorporating information on grizzly bear habitat utilization. Insufficient information is contained at the individual polygon, or component, level pertaining to important factors such as equity of seasonal feeding opportunities and landscape patterns of food availability. At the unit level, too much extraneous information may obscure recognition of the most energetically efficient area that a grizzly bear can use. Subunits will be delineated once habitat mapping of the unit is complete.

HABITAT SUBMODEL

Description

The habitat submodel provides a relative numeric evaluation of grizzly bear habitat expressed as "habitat value." Habitat value can reflect both potential and existing conditions and incorporates food, cover, habitat diversity, and equity of seasonal feeding opportunity. Value attributable to denning habitat is not incorporated directly in the submodel because denning habitat is not considered to be limiting in the Yellowstone ecosystem (Judd and others, in press).

The habitat submodel provides a habitat value (UHV_i) for each bear management unit. This

value (UHV_j) is an average of subunit habitat values ($SUHV_{pi}$) weighted by relative area. Subunits are therefore the primary management level at which grizzly bear habitat values are calculated. Subunit habitat values are relative and thus meaningful only in comparison to other units or subunits.

Habitat value of a subunit (10000 to 40000 ha) depends not only on average food and cover values but also on diversity attributable to edge density and on the consistency or equity of feeding opportunity across seasons during which bears are actively foraging. Landscape diversity or edge density and seasonal feeding opportunity equity are treated as attributes of a management subunit in this model and only indirectly as attributes of a management unit. Subunit values ($SUHV_{pi}$) are therefore a direct function of mean habitat value (MHV_{pi}), which incorporates the effect of edge density and of seasonal subunit value equity (E_{pi}).

Increased continuity of feeding opportunity across seasons is considered to increase the habitat value of a subunit. Evenness or continuity of feeding opportunity would logically result in greater fidelity of bears to an area (subunit). This greater fidelity is a probable consequence of increased efficiency of habitat exploitation. Thus, as disparity of subunit seasonal values (SHV_{pik}) increases, mean subunit habitat value (MHV_{pi}) decreases.

An index, E_{pi}, of seasonal feeding opportunity equity is utilized in submodel calculations. E_{pi} is an adjusted coefficient of variation for seasonal subunit habitat value (SHV_{pik}). Decreased E_{pi} corresponds to increased disparity in seasonal values. MHV_{pi} is therefore reduced as a direct function of E_{pi}'s fractional value which is constrained to a minimum value of 0.667.

Mean subunit habitat value (MHV_{pi}) is the average seasonal subunit values (SHV_{pik}) calculated for spring, summer, and fall. SHV_{pik} is an area-weighted mean of individual component habitat values (HV_{jku}). Subunit habitat value (SHV_{pik}) primarily reflects foraging opportunity, although value attributable to thermal and security cover is also integrated. Greater seasonal habitat value primarily reflects greater quality and diversity of available foods over a broader area.

Individual component habitat values (HV_{jku}) are derived from base unit area component habitat values (UHV'_{jku}). Base unit area component value integrates value of characterisitic available foods, diversity of feeding opportunity, and feedsite density or preference for each habitat component by season (spring, summer, or fall) (Mattson and others this volume). Two factors are applied to base unit area values (UHV'_{jku}) to derive individual component values (HV_{jku}): (1) adjustment (Cvr_{tk}) based on a specific distance threshold from forest-nonforest edge into both forest and nonforest stands (table 1) and (2) adjustment (Ung_{tk} or Trt_{tk}) based on inclusion in protein-rich areas (table 2).

Grizzly bears are known to prefer forest-nonforest ecotones in the Yellowstone ecosystem (Graham 1978; Blanchard 1983; Brannon 1984; Schleyer and others 1984). Base unit area component values are adjusted according to distance from an ecotone, with coefficients defined by frequency distribution of recorded feedsites. Yellowstone grizzly bears also prefer ungulates and cutthroat trout (Cole 1972; Schleyer 1983; Knight and others 1984). An additional factor is applied to base unit area values that accounts for value added by extensive concentrations of protein-rich foods. This adjustment varies according to the type of protein-rich food and, for ungulates, the season and type of range.

Base unit area habitat values (UHV'_{jku}) range from a maximum of 1.291 to a minimum of 0. Base unit area values also vary for each component according to presence of ungulate concentrations and season. A benchmark base value of 1.000 is accorded the habitat type (unadjusted for cover type) with greatest seasonal value. Tabular values for the base unit area components are available from D. Mattson.

In this submodel, habitat components correspond to combinations of habitat type and cover type. Comparison of tabular values is meaningful only when stratified by presence (UNG) or absence (W/O UNG) of protein-rich food concentrations. Comparison between the two strata or categories is legitimate only after multiplying the UNG value by an appropriate factor (Ung_{tk} or Trt_{tk}) adjusting for the type of protein-rich food present and the type of ungulate range.

In summary, calculated subunit habitat value varies according to area representation and base unit area value of habitat components, presence of ungulate concentrations and cutthroat trout spawning streams, interspersion of forest and nonforest components, equity of feeding opportunity through the bears' active seasons, and habitat type diversity. Highest values correspond with subunits having concentrations of ungulates, trout spawning streams, high habitat diversity, equity of seasonal feeding opportunity, habitat components with uniformly high base unit area values, high density of forest-nonforest edge, and forest cover at optimal successional stages.

Variables

A_{pij} = total area representation of habitat component j in subunit i of unit p.

SUA_{pi} = total area of subunit i in unit p.

UA_{p} = total area of unit p.

P_{pih} = proportionate area representation of habitat type (or habitat type aggregate) h in subunit i of unit p.

UHV'_{jku} = base unit area value of component j during season k in protein-rich strata u.

Trt_{tk} = adjustment factor for inclusion in influence zone of cutthroat spawning stream type t during season k.

Ung_{tk} = adjustment factor for presence of ungulate concentrations on range type t during season k.

Cvr_{tk} = adjustment factor for distance zone x from forest-nonforest edge into cover type t during season k.

$HV_{jku} = UHV'_{jku} * Cvr_{xtk} * (Trt_{tk}$ or $Ung_{tk})$

$SHV_{pik} = (\sum_{j=1} A_{pij} * HV_{jku})/SUA_{pi}$

$MHV_{pi} = (\sum_{k=1} SHV_{pik})/3$

$E_{pi} = 1-(SHV_{pik}-MHV_{pi})^2/MHV_{pi})/4$ $.242)$

$SUHV_{pi} = MHV_{pi} * E_{pi}$

$UHV_{p} = (\sum_{i=1} SUA_{pi} * SUHV_{pi})/UA_{p}$

Assumptions

1. Area habitat quality is substantially a function of cover and food availability.

2. Where human presence is not a factor, food availability considerably outweighs cover and denning habitat in contribution to area habitat value or quality.

3. Feeding-site, scat, and radio location data collected by the IGBST are representative of the grizzly bear population in the greater Yellowstone area.

4. Habitat type, with cover type superimposed, is an accurate predicator of food and cover value for grizzly bear within an area of 10000 to 40000 ha.

5. Subunit habitat value is accurately predicted by habitat diversity, equity of feeding opportunity through the bears' active seasons, habitat type (or component) representation, and presence of animal food sources.

Operation

Successive incorporation of habitat values culminating in grizzly bear management unit habitat values is as follows:

UHV'_{jku} - base unit area component habitat value

HV_{jku} - unit area component habitat value

SHV_{pik} - seasonal subunit habitat value

MHV_{pi} - mean subunit habitat value

$SUHV_{pi}$ - subunit habitat value

UHV_{p} - management unit habitat value

DISPLACEMENT SUBMODEL

Description

The displacement submodel quantifies the effects of disturbance associated with human activities on the grizzly bear's ability to use an area. The interaction of habitat quality and displacement determines the habitat effectiveness (actual carrying capacity). The following steps were used to develop this submodel: (1) stratify all activities and human uses occurring in the Yellowstone Ecosystem into groups reflecting similar effects; (2) assign disturbance coefficients and zones of influence for each activity group; (3) identify how the effects of disturbance for a specific area or project are aggregated in space and time; and (4) identify the procedures to operate the submodel.

Variables

Activities and human uses that occur in the Yellowstone ecosystem were stratified into groups having similar disturbance potentials. Activity lists typically reflect the type of user or function responsible for the activity (e.g., timber harvest, campground, or oil and gas drilling). Such an activity list would be lengthy. Grouping activities by the degree

and type of disturbance not only reduces the number of categories but also simplifies the analysis without giving up model resolution.

Thirteen activity groups, stratified by the following criteria, were identified:

1. Type of activity (motorized, nonmotorized, or explosive)
2. Nature of the activity (linear, point, or dispersed)
3. Length of activity (diurnal or 24-hour)
4. Disturbance intensity (high or low)

The type of activity is determined by the dominant disturbance element associated with the activity. If the activity is primarily mechanized and produces loud equipment noises, it is motorized. Otherwise, it is nonmotorized. With above-ground explosives, the activity type is explosive. The activity groups, including definitions and specific examples of activities, are shown in table 1.

Disturbance Coefficients/Zones of Influence

Disturbance coefficients and zones of influence for each activity group were identified using the team's subjective ratings. Available research data were collected primarily in other grizzly bear ecosystems and not considered representative of grizzly behavior in the Yellowstone ecosystem. The zone of influence identifies the distance in which grizzlies would be affected by the activity, and the coefficient identifies the degree of disturbance (on a scale of 0.0 to 1.0) within the zone of influence. When selecting the zone of influence, ridgeline and line-of-sight distances are used when they are less than the mileage estimate. Disturbance can influence bear use in two ways: actual displacement and change in use patterns that reduce the time available for a bear to use an area (for example, 24-hour to nocturnal use periods). Both of these factors were considered in coefficient development. Cover was considered important in determining both the zone of influence and the degree of disturbance. Cover is defined as that vegetation capable of hiding 90 percent of a standing adult bear from view of a human at a distance equal to or less than 60 m. Separate values were developed for cover and noncover situations. Another consideration in coefficient development was habituation to recurring (predictable), nonthreatening activities. Attractions associated with various activities that might override the bear's flight response were not considered in this submodel. Attractions associated with a given activity are a key element in the mortality submodel.

We did not assume that all bears would be displaced from an activity's zone of influence. Instead we estimated what percent of the bears would still use the zone of influence for what percent of the 24-hour period. A disturbance coefficient of 0.0 means that none of the zone of influence would be available (total displacement for the life of the activity) to the bear. A disturbance coefficient of 1.0 means that habitat effectiveness is not affected by the activity. A coefficient of 0.5 means that either one half of the bears are displaced, all the bears can use the area for only half the day, or any combination thereof. The result is the same--the ability to support bears is reduced by 50 percent. Table 2 shows the disturbance coefficients and zones of influence for the 13 activity groups.

Based on the assumption that bears are sensitive to multiple simultaneous sources of disturbance, disturbance within overlapping zones of influence is cumulative. In the habitat effectiveness calculation, the coefficient cannot be greater then 1.0.

The timing and duration of an activity may be as important as its disturbance coefficient in determining the effects on grizzly bears. Activity duration is another input coefficient into the submodel. This coefficient is simply the proportion (0.0 to 1.0) of the activity's duration in relation to the assessment period. The assessment period's length can vary with the detail of the analysis. For most applications a monthly assessment period, aggregated by season (spring, summer, fall, denning) seems appropriate. In special circumstances, daily assessment periods could be used. The capability to identify activity bottlenecks and opportunities for activity schedule coordination (fig. 2) can be refined with shorter assessment periods. These coefficients are multiplied against the product of the disturbance coefficient and optimal acres (habitat quality) to determine the habitat effectiveness for the entire assessment period.

Habitat quality determines the ability of a specific habitat to support a bear (habitat submodel). Disturbance determines the ability of a bear to use a specific habitat (displacement submodel). Habitat effectiveness is the product of these two submodels and identifies the habitat's actual capability. Habitat effectiveness is determined using (1) the polygon's optimal acres (for example, 40 acres of 0.5 quality rating equals 20 optimal acres), (2) percent of the unit affected by the zone of influence, and (3) the disturbance coefficient involved. The product of these three factors divided by the total optimal acres equals the percentage loss in habitat effectiveness.

The mortality submodel is only indirectly linked with the disturbance submodel. Displacement of bears from one area to another

Table 1. -- Definitions and examples of groups of human activities

MOTORIZED LINEAR: Motorized activities restricted to roads, trails, or linear corridor of travel such as aircraft flight corridors or seismic lines.

HIGH USE: Vehicle traffic exceeding one vehicle per daylight hour, including recurring low-elevation (less than 500 m above-ground) aircraft use, or seismic exploration without above-ground explosives.
LOW USE: Vehicle traffic less than one vehicle per daylight hour, generally associated with primitive roads or jeep trails.

MOTORIZED POINT: Motorized activities restricted to a specific point or area such as drilling operation, timber harvest activities, boat dock or ramp, generator site, or resort complex.

DIURNAL: Activities that produce loud equipment noises and occur only during the daylight hours.

HIGH INTENSITY: for example, major timber harvest activities, or day-use-only recreation complex.
LOW INTENSITY: for example, firewood cutting.

24-HOUR: Activities that produce loud equipment noises during a 24-hour operating period; for example, oil and gas drilling operation, mill or minesite, or resort complex.

MOTORIZED DISPERSED: Concentrated off-road vehicle activities that are not restricted to roads or trails, but that occur over broad areas. Use must be greater than one person per habitat component per day, including either overland (motorcycle) or over-snow (snowmobile) activities.

NONMOTORIZED LINEAR: Nonvehicle use associated with roads or trails, including roads closed to motor vehicle traffic.

HIGH USE: greater than three parties per day.
LOW USE: less than three parties per day.

NONMOTORIZED POINT: Human activities restricted to a specific point or area.

DIURNAL: for example, picnic ground or trailhead.
24-HOUR: for example, campground or summer home.

NONMOTORIZED DISPERSED: Human activities not restricted to a linear corridor or a specific point.

HIGH USE: Greater than one person per habitat component per day; for example, concentrated hunting use area.
LOW USE: Less than one person per habitat component per day; for example, area without easy access or without recreation attractions.

EXPLOSIVES: Activities in which very loud explosions are associated with the activity; for example, seismic exploration or road construction.

could influence the exposure to mortality risks identified in the mortality submodel. This relationship must be kept in mind when interpreting the model outputs.

Operation

The following procedures are used in the displacement submodel. (1) Identify and map all existing activities and human uses within a selected bear analysis unit. Complete a separate map for each assessment period based on identified activity durations, and selected assessment period stratification. (2) For each map, identify zones-of-influence and disturbance coefficients (from table 2). (3) Overlay habitat polygon maps and maps of activity zones-of-influence and identify for each polygon involved the percentage of polygon overlapping a given zone-of-influence, the appropriate disturbance coefficient (DC) for each zone-of-influence, and the appropriate duration coefficient for each zone-of-influence. Sum the disturbance coefficients for any overlapping zones-of-influence. (4) Compute the existing habitat effectiveness for each assessment period. Habitat quality must reflect appropriate seasonal rating. (5) Do the same for any proposed activities or human uses on a projected yearly basis for at least a 5-year planning period.

Table 2. -- Disturbance coefficients (DC) and zones of influence (ZI) for cover and noncover by activity group

Activity group	Cover		Noncover	
	ZI	DC	ZI	DC
Motorized Linear, high use	ridge line, 0.8 km	0.7	ridge line, 3.2 km	0.6
Motorized Linear, low use	ridge line, 0.8 km	0.9	ridge line, 3.2 km	0.8
Motorized Point, diurnal high intensity	ridge line, 1.6 km	0.5	ridge line, 3.2 km	0.4
Motorized Point, diurnal low intensity	ridge line, 1.6 km	0.7	ridge line, 3.2 km	0.6
Motorized Point, 24-Hour	ridge line, 1.6 km	0.2	ridge line, 3.2 km	0.1
Motorized Dispersed	N.A.	0.5	N.A.	0.4
Nonmotorized Linear, high use	0.2 km	0.8	line-of-sight, 0.8 km	0.7
Nonmotorized Linear, low use	none	1.0	line-of-sight, 0.8 km	0.9
Nonmotorized Point, diurnal	0.5 km	0.8	line-of-sight, 0.8 km	0.5
Nonmotorized Point, 24-Hour	0.5 km	0.5	line-of-sight, 0.8 km	0.3
Nonmotorized Dispersed, high use	N.A.	0.8	N.A.	0.7
Nonmotorized Dispersed, low use	N.A.	1.0	N.A.	0.9
Explosives	ridge line, 1.6 km	0.5	ridge line, 3.2 km	0.3

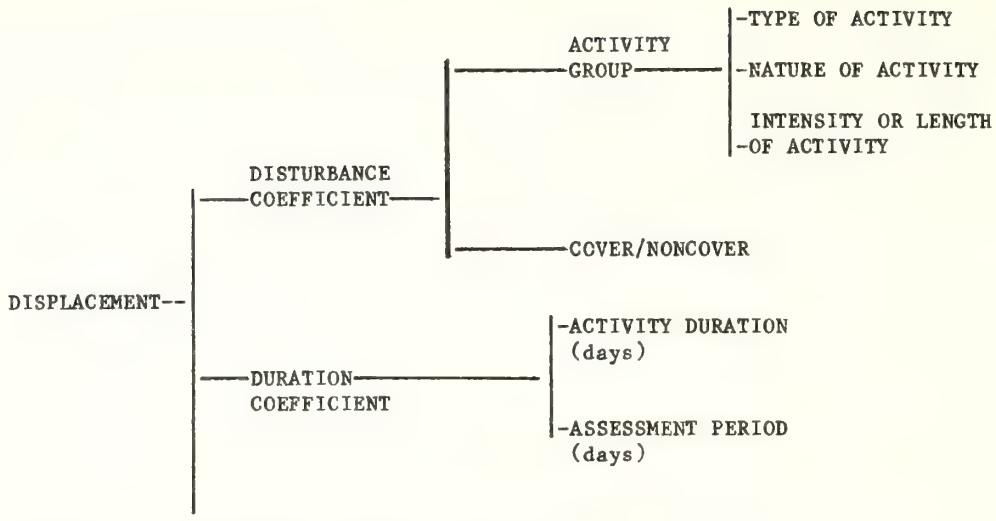


Figure 2. -- Displacement submodel diagram

MORTALITY SUBMODEL

Description

Human-caused mortality of grizzly bears within the Yellowstone ecosystem continues to be one of the most significant deterrents to population recovery. Thus, it is necessary to evaluate the risk of grizzly bear mortality due to human activity in the cumulative effects process. The mortality submodel provides a relative quantitative evaluation of this risk. The mortality submodel results in a mortality risk index for each bear management unit and or subunit.

Variables

Five basic variables are incorporated into the mortality submodel: (1) habitat quality, (2) nature of activity (point, linear, dispersed), (3) intensity of use, (4) availability of attractants, and (5) presence of firearms. These five basic variables combine to form distinct activity groups for which mortality risk indices were developed.

Habitat Quality--Deciding whether an activity occurs in low- or high-quality habitat is primarily based on management situation stratification under the "Interagency Grizzly Bear Guidelines." Activities occurring in Situation 1 are categorized as high-quality habitat while activities occurring in Situation 2 areas are categorized as low-quality habitat. Activities occurring in management Situation 3 areas and private lands fall into the quality habitat immediately adjacent to it. Although it is recognized that habitat quality can vary within a stratified area, stratification by management situation is currently the most consistent measure of habitat quality. As habitat mapping and habitat values are calculated according to the habitat submodel, habitat quality can be further refined.

Nature of Activity--Potential sources of illegal human-caused mortality can be categorized into the three groupings established in the displacement submodel. Point source activities include those activities by which humans may provide grizzly bears with a food attractant (backcountry camps with food, livestock feed, game meat; private homes; road-killed animals; developed campgrounds; bear-baiting stations; domestic sheep allotments).

Linear sources include roads, trails, and stream corridors where grizzly mortality could occur. Linear sources are divided into 10-mile segments (e.g., 20-mile road equals two sources, 8-mile trail equals one source). Dispersed sources would include those activities not associated with point and linear sources (e.g., hunting off the trail or road, berry picking, hiking off trail, cross country skiing). Dispersed sources are measured in units of people per habitat component per day. Mortalities associated with dispersed sources would be associated with random grizzly bear-human encounters.

Intensity of Use--Intensity of use on both linear and dispersed sources is categorized by the following activity levels:

Low use: Roads, fewer than one vehicle per daylight hour
Trails/Roads closed to vehicle, fewer than three parties per day
Dispersed, fewer than one person per habitat component per day

High use: Roads, more than one vehicle per daylight hour
Trails/Roads closed to vehicles, more than three parties per day
Dispersed, more than one person per habitat component per day

Availability of attractants--Availability of attractants at point sources of activity has been a significant factor in grizzly bear mortality throughout the ecosystem.

Food attractants available: if food storage requirements are in effect, but not enforced.
Food attractants unavailable: if food storage requirements are enforced.

Presence of firearms--Although grizzly bears are protected within the Yellowstone ecosystem, numerous mortalities by firearms have been recorded. Yellowstone and Grand Teton National Parks have regulations prohibiting the carrying of firearms, but the remainder of the area has no such regulations. Risk of bear mortality is considered higher on those lands allowing firearms.

Firearms present: if there are no restrictions on the public carrying firearms (generally includes all lands other than those within the National Parks).
Firearms absent: if firearms cannot be carried by the public (generally includes all lands within the National Parks).

Mortality risk indices for each activity group were developed by categorizing each human-caused grizzly mortality occurring in the ecosystem from 1973 to 1983. Mortality data were obtained from Kenneth J. Greer, Montana Department of Fish, Wildlife and Parks. Specific data on individual mortalities not available from K. Greer were obtained from individuals who have investigated the mortalities.

Mortalities were then adjusted upward for all categories with known losses due to firearms. This increase was based on the fact that all mortalities associated with firearms are not reported. Knight and Eberhardt (1985) reported that during the 1973 to 1983 period, calculations suggest that roughly 56 to 70 percent of the actual mortalities may have been recorded. Activity groups with known firearm losses were increased by a factor of 1.4 to reflect nonreported mortalities. The mortality risk index is simply the adjusted losses for each activity group divided by the total number of adjusted losses (table 3).

Due to a relatively small sample size, several categories have indices of 0. Managers must be aware that cumulative activities in these apparent low-risk categories may increase mortality risk.

As mortality factors may change over time due to improved management enforcement, mortality indices should be calculated annually using the past 5 years to reflect recent changes in mortality sources. This information will allow managers to evaluate and compare current management practices against the original data set. These mortality indices, however, would not be used in the calculation of the baseline mortality risk index for a bear management unit or subunit.

Assumptions

1. Mortalities include all dead bears as well as live bears removed from the ecosystem.

2. Only human-caused, illegal grizzly bear mortalities are included in the mortality indices. No legally killed bears (hunting) or mortalities associated with research activities are included.

3. Distribution of mortalities does not differ throughout the period in a manner that would significantly alter the mortality indices.

4. Prior to 1983, bears were removed at point sources because attractants were available, unless specific evidence indicated otherwise.

5. All human-caused but nonfirearm mortalities are reported.

Operation

1. List all existing activities from habitat effectiveness submodel for a bear management unit and/or subunit.

2. Categorize activities as to whether they are point, linear, or dispersed for each assessment period.

3. Assign to each activity values for intensity of use and availability of attractant.

4. Determine whether firearms can be legally associated with the activity.

5. Select mortality index from table 3 and assign to each existing activity.

6. Add mortality values for each bear management unit and/or subunit.

The value generated for each activity is not the probability of a grizzly bear mortality for a specific activity but an index of risk. The cumulative mortality index for the bear management unit or subunit is a quantitative assessment of the mortality opportunities. The higher the value, the higher the risk of a grizzly bear mortality.

Table 3. -- Mortality risk and indices by activity group

				Known Losses (1973-1983)	Adjusted Losses (1973-1983)	Mortality Index
HIGH HABITAT QUALITY	POINT	Attractant Available	Firearms	14	19.6	.29
			No Firearms	15	15	.22
		Attractant Unavailable	Firearms	0	0	.00
			No Firearms	1	1	.02
	LINEAR	High Use	Firearms	0	0	.00
			No Firearms	3	3	.04
		Low Use	Firearms	0	0	.00
			No Firearms	0	0	.00
	DISPERSED	High Use	Firearms	1	1.4	.02
			No Firearms	0	0	.00
		Low Use	Firearms	6	8.4	.13
			No Firearms	0	0	.00
LOW HABITAT QUALITY	POINT	Attractant Available	Firearms	7	9.8	.15
			No Firearms	9	9	.13
		Attractant Unavailable	Firearms	0	0	.00
			No Firearms	0	0	.00
	LINEAR	High Use	Firearms	0	0	.00
			No Firearms	0	0	.00
		Low Use	Firearms	0	0	.00
			No Firearms	0	0	.00
	DISPERSED	High Use	Firearms	0	0	.00
			No Firearms	0	0	.00
		Low Use	Firearms	0	0	.00
			No Firearms	0	0	.00

THRESHOLD LEVELS

A final step in the development of a cumulative effects model involves establishing and validating threshold levels. These thresholds represent the minimum acceptable levels of habitat effectiveness and mortality risks required for species recovery. Thresholds could vary by season and by bear management unit.

Ideally, thresholds for habitat effectiveness should provide for the energetic and spatial needs of the grizzly bear population during worst-case situations (seasonally and annually). One possible approach would be to compare worst-case home range versus lifetime home range (seasonal and annual ranges) of a representative set of adult female bears with multiyear histories of telemetry locations. Even approximate calculations of available energy for different seasons and years would greatly enhance our understanding and modeling of spatial needs of grizzly bears. By analyzing bears' spatial use in areas of comparable energetic value but with differing levels of human activity, it may be possible to assess the influence of human activity.

Establishing and validating threshold levels based on bears' response to varying environmental conditions and human activity will require habitat mapping of several bear management units and intensive analysis of the existing data. With declines occurring in the grizzly bear population index and in key population parameters (Knight and Eberhardt 1985), it would be desirable to establish interim thresholds for the habitat effectiveness value and the mortality index. The following thresholds for interim guidance are recommended throughout the Yellowstone ecosystem.

Habitat Effectiveness

Within each bear management unit, habitat effectiveness values should be retained at least at the current level. However, when the current level is below 80 percent of potential habitat effectiveness, reaching 80 percent becomes a minimim goal. To safeguard against losses of seasonally significant habitat, managers should measure and maintain suitable habitat on a seasonal basis.

Mortality Index

Human-caused grizzly bear mortality, particularly of adult females, is the key issue in conserving the grizzly bear population in the Yellowstone ecosystem (Knight and Eberhardt 1985). We recommend that the mortality index ceiling for each bear management unit be no higher than existing levels. Decreasing the existing index, particularly in the category of available attractants at point sources, should be an immediate priority.

MANAGEMENT OF CUMULATIVE EFFECTS

The cumulative effects model will enhance decision making for land and resource managers in several ways. First, it will provide the manager a quantified and graphic representation of the effective habitat values and mortality risks for the existing (as well as potential) situation. The manager then can use the computer to simulate the additive as well as the independent effects of different land uses (existing or proposed). In other words, the manager can ask a series of what if?? questions and explore the relative consequences. The CEM should also enable the manager to discriminate which land use is contributing most to the simulated effects (sensitivity) and whether it influences habitat, habitat use, and/or survivorship of grizzly bears. This can be done in space and through time and at different planning levels.

Hence, through the CEM, the manager can enhance decisions concerning grizzly bear recovery and other land management issues.

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CARTOGRAPHIC MODELING: A METHOD OF CUMULATIVE EFFECTS APPRAISAL

David S. Winn and Kim R. Barber

ABSTRACT: The basic assumptions and implications of developing a wildlife habitat cartographic model are discussed. A cartographic model and Geographic Information System were used to evaluate the cumulative effects of management activities on free-ranging grizzly bear (Ursus arctos horribilis) habitat within the Greater Yellowstone Ecosystem. The habitat characteristics associated with bear unit values, habitat diversity, and edge use were evaluated by comparing habitat conditions in various buffer sizes surrounding grizzly bear radio location sites with a similar number of randomly located sites. The cartographic modeling process is outlined and the model's utility for evaluating management implications and research needs are summarized.

INTRODUCTION

The cumulative effects issue is not new. Its present modeling emphasis responds to a concern for a more holistic approach to the land and resource management of grizzly bear habitats and the need to evaluate the impacts of management activities at the ecosystem level.

As early as 1971 the National Environmental Policy Act required that the effects of management activities be examined in an integrated and far-reaching manner. More explicit guidelines for conducting these environmental analyses were provided by the Council on Environmental Quality (CEQ) in 1978. The Endangered Species Act (1973) requires that biological assessments evaluate the cumulative effects of land uses and management activities on grizzly bears (Ursus arctos horribilis). This Act defines cumulative effects as the combined effect upon a species or its habitat that results from an activity.

The assessment and evaluation of long-range impacts and consequences of any project include the vexing problem of estimating direct and indirect effects. In essence, what must be dealt with are the direct effects caused by an action, the indirect effects of that action, and the resulting chain of successional events within the habitat.

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As with most models, data must be converted into information. Second, information must be converted into ideas that are clear, concise, and meaningful. In addition, we should not lose sight of the major planning objectives: converting data to useful information for the purpose of making management decisions.

Throughout the evolution of land management planning, various models have been developed. These models, in spite of their complexity, have the simple goal of converting data into information.

In addition, models can provide the following benefits:

1. Once the conceptual ideas and methods associated with data conversions and model development are documented and reviewed by the public, the planning "products" are generally accepted.

2. Several variables can be made to interact, which enhances our ability to accurately display and interpret an array of relationships.

3. Models provide a medium for learning and for gaining understanding.

4. Finally, models permit validation of the theories from which they are derived.

The primary purpose of this paper is to demonstrate a process, not to defend a model. In simplistic terms, we formulated rule sets, organized a data base, and tested hypotheses within the model. The goal of the process is to gain understanding and to ensure the recovery of wild, free-ranging grizzly bears within the ecosystems.

ESSENTIALS OF CARTOGRAPHIC-CUMULATIVE EFFECTS MODELS

Cartographic modeling is a process that reduces the task of combining several spatial information sets into one (fig. 1). This orderly transformation follows a biological rule set. These rule sets are merely mathematical descriptions of orderly biological relationships.

Generally speaking, cartographic models that successfully address land management issues have three similar characteristics:

1. Data are converted to information in an orderly biological sequence.

2. Basic processes are followed.

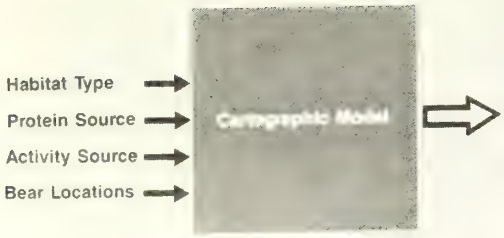


Figure 1.--General flow of habitat and bear locational information through the grizzly bear cartographic model.

3. The process can incorporate successional change.

The data relate to conditions that are spatial, such as the exact location of a bear's den, and nonspatial, such as the number of bears in a drainage.

Some of the more advanced techniques for converting resource data into meaningful management information include Geographic Information Systems (GIS). The GIS process provides for:

1. Identifying each data bit with a ground location.

2. Displaying data bits in relationship to time and space or in relationship to the spatial arrangements of other data bits. In other words, the juxtaposition of an array of plant communities and activities can be addressed.

3. Storing, analyzing, and displaying the results of the data set.

4. Displaying successional events.

Basic to the operation of a GIS is the conversion of habitat data to polygonal data. In this model, polygonal data represent the mapped outline of individual plant communities. The Greater Yellowstone Ecosystem (GYE) grizzly bear model defines the mapped polygons by their habitat type-overstory conditions. Polygons become the basic units of habitat and carry the attribute values. Polygons are assigned habitat type-overstory values that represent habitat potential, successional stage, and value to the bear.

The definition of rule sets is the most important element of bridging the gap between the cumulative effects process and the cartographic model. In the case of cumulative effects models, the rule set is merely the converting of spatial, nonspatial, and ecological relationships into mathematical functions. It is the power of these mathematical functions that makes the model useful. The processof converting these relationships into mathematical functions is important, because it makes it possible to distinguish science from planning and conjecture.

Romesburg (1981) suggested that persistent confusions associated with conceptual definitions, such as carrying capacity or viable populations and the reliability of knowledge gained from computer simulations, stem from either inadequate use or misuse of scientific methods. For purposes of cartographic modeling, Romesburg's thesis makes an additional important point: the domains of science and planning are philosophically distinct; yet because they share similar tools of analysis and simulation, their differences pass unnoticed.

It is this point that is critical to the interpretation and development of cartographic model rule sets. Ecological modelers and planners must recognize the essential difference that science uses fact as its standard for selection and planning relies on a value set.

The conflict in cumulative effects modeling arises when value is not fact or when value added to value is assumed to be fact. For example, in issues involving timber, the term "forage-cover ratio," depending on your point of view, spans a spectrum ranging from science to conjecture. The actual data base ratio is fact, but its biological interpretation at times can be construed to be fact.

In wildlife science, assumptions sometimes soften the impact of conjecture. There are two major assumptions that provide the foundation for the GYE Cumulative Effects Model: (1) habitat selection by grizzly bears does occur, and (2) area familiarity provides for efficient exploitations of the habitat resources. In other words, the process of becoming familiar with the habitat has survival advantages. This idea translates into the concept that area familiarity subsidizes efficiency (McLellan this volume).

From the premise that habitat selection occurs come three more assumptions implicit in the first:

1. Bears can detect resource differences.

2. Bears can determine which resources provide their needs.

3. Bears are capable of learning where to find these resources.

If these assumptions are correct, a bear will always be at a site it has selected and the sampling of bear locations will represent resource selection.

It was from the notion that grizzly bears actively select resources that a cumulative effects rule set was developed to appraise management activity-bear interactions within the Greater Yellowstone Ecosystem.

REATER YELLOWSTONE CARTOGRAPHIC-CUMULATIVE FFECTS MODEL

he concept of determining the cumulative effects or grizzly bears and their habitat is not new Christensen and Madel 1982). It began in the orthern forest ecosystems and has been evolving hroughout several ecosystems for the last 4 years. he development of a cartographic model for specific ecosystems entails several initial steps:

1. The classification and mapping of habitat omponents.

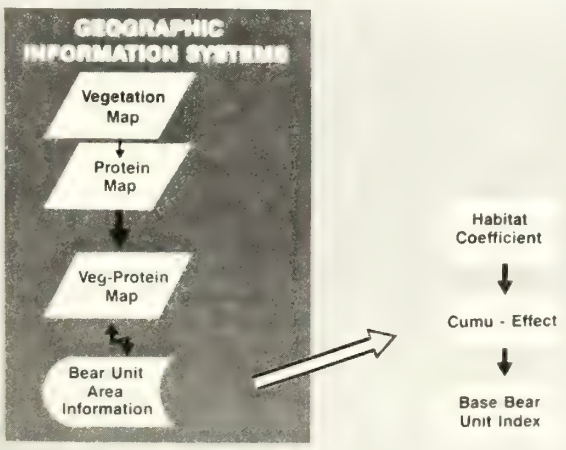
2. The categorizing and mapping of land use ctivities.

3. The development of interactive habitat oefficients.

he general idea appears simple enough; however, he process of linking activity patterns, habitat uality evaluations, disturbance factors, and the isk of mortality is a cumbersome task.

he cartographic model developed for the Greater ellowstone Ecosystem cumulative effects model ncorporates a GIS that produces redefined polygon oundaries and summations of habitat component cres. This is accomplished with a series of egetation-protein-activity overlays (Winn and arber in press). A species-specific software utputs equivalent acres, diversity indexes, and ear unit values (fig. 2).

ear management units are used as a standard for omparing management activities. These units, hich are delineated by using grizzly bear radio ocations and topographic features, serve to break he larger Greater Yellowstone Ecosystem into anageable areas. In addition, bear units facilitate the cumulative effects analysis process,



'igure 2.--Flow chart depicting the cartographic iodeling of a bear unit index.

correspond to individual bear use patterns and behavioral ecology, moderate the washing-out effect associated with the analysis of management activities at the ecosystem level, and set a standard area size with which to compare interunit analyses.

Bear management units are further divided into subunits. The subunits, which are delineated on the basis of seasonal bear use patterns and interspersion of seasonal ranges, provide the optimal scale for landscape resolution and modeling of bear habitat use patterns. Within the model, the subunit represents the most energetically efficient area for the bear and is the basis for cumulative effects calculations.

The GYE Cumulative Effects Model consists of three submodels:

1. The habitat submodel incorporates the variables food, cover, habitat diversity, and seasonal feeding opportunities. The submodel outputs a relative habitat index (Mattson this volume; Weaver and others this volume).

2. The displacement submodel permits the interaction of management activities across a spectrum of activity intensity and duration. The submodel's function is to identify the area in which bears will be affected and the extent to which bear activity will be reduced (Weaver and others this volume).

3. The mortality submodel, which is not yet an active component, determines the risk of mortality associated with the interaction of habitat quality and activity duration and intensity (Weaver and others this volume).

In summary, the habitat submodel determines the capacity of habitat to support bears. The displacement submodel predicts the actual use of the area by bears. The outputs from the habitat and displacement submodels are used to calculate a habitat effectiveness index. It is this index that is used to evaluate management alternatives. To review the cartographic process, habitat components are mapped and each polygon is labeled with the model attributes that identify its habitat type-overstory condition and the presence or absence of concentrated protein food sources. This habitat layer and the existing management activity overlays are digitized.

Next, the model's displacement coefficients (table 1), which reflect management activity duration and intensity, are used to define the impacted buffer area around each activity. Then the effect for each management activity is calculated and aggregated into a subunit cumulative effects value.

Initial buffer areas calculated by the cartographic model were limited to individual forest and nonforest radii associated with specific activity displacement coefficients. The resultant area, a circle, was not sensitive to differences in cover-noncover coefficients.

Table 1.--Greater Yellowstone cumulative effects displacement coefficients[1] that define buffer and zone of influence radii for selected activities

Activity type	Displacement coefficient	
	Forest	Nonforest
	Miles	
Motorized point	1.0	2.0
Nonmotorized point	.3	.5
Road	.5	2.0
Trail	.1	.5

[1]Weaver and others this volume.

To overcome the initial buffer's lack of cover sensitivity, the spoke file was developed. The computer-generated map file incorporates both noncover and cover displacement factors into a zone of influence. Radii at 3° intervals evaluated the presence of noncover or cover and defined the boundary of the zone of influence. In the example of a motorized activity (table 1), as radius passes through 1 mile of noncover, 50 percent of the buffer requirement is met. If the radius continues into cover for 1/2 mile, the buffer requirement is fulfilled. Thus, any given radius can pass through any combination of cover/noncover to fulfill the buffer requirement. When all the radii end points are connected, they outline the zone of influence. The procedure is simply the accumulation of proportional distances based on activity cover and noncover displacement coefficients.

The zone of influence is more sensitive to juxtaposition of vegetation types and smaller than initially constructed for buffer zones.

In broad terms, the activity buffers are overlaid on the vegetation-protein base. The GIS interacts with the displacement subroutine and the area of the impacted polygons is determined. The updated GIS area summary is transferred to the species-specific habitat coefficient subroutine, and polygons are reevaluated. The resulting cumulative effects are evaluated as equivalent acres (sum of individual polygon coefficient X polygon acres). Subunit equivalent acres are modified by an estimate of habitat diversity and summed into the final cumulative effects index.

MODEL TESTING

Major variables for the cumulative effects model were tested using the Pilot Peak (Shoshone National Forest) fall season vegetation data base and the selected displacement coefficients (table 1). The Pilot Peak area was chosen because it resembles characteristic size and habitat conditions of a bear management subunit. The area includes a minimal number of linear and point source activities. For purposes of the following discussion, we assumed these activities did not influence bear behavior.

To test the cumulative effects model, we compared calculated area characteristics and habitat type proportions of randomly located buffers to the overall bear subunit value. With the exception of habitat diversity, the random plots did not deviate significantly ($P<0.05$) from the expected results. Thus, we accepted the premise that the random plots represented the base habitat condition. This step was necessary to eliminate biased estimators associated with buffer area size differences.

We then compared the randomly located buffers to similar-sized buffers associated with bear locations. Significant differences occurred among these comparisons.

The basic assumption associated with this comparative procedure is that in the absence of active selection by bears, habitat use would be proportional to its availability. Since we found resource use was not proportional to its availability, we concluded the model predicted that habitat selection by bears occurs.

Once this assumption was accepted, we took advantage of the validation process that is inherent within the cartographic model.

RESULTS AND DISCUSSION

Size of Zones of Influence

We compared the zone of influence calculations for random plots with bear relocations and found that:

1. As the zone of influence area increased, bear use was disproportionately associated with higher quality habitat; however, due to the interaction of the current diversity calculation, bear unit values are area-size dependent (fig. 3).

2. The initial diversity index, which represented an evaluation of cover and feeding opportunities, is strongly area-size dependent and its emphasis is exaggerated in the model (fig. 4). This is being corrected (Mattson in this volume).

3. Because the proportion of equivalent acres to total acres is not sensitive to unit area, we envision this proportion as a possible replacement for the diversity index as an indicator of habitat quality (fig. 5).

Use of Edge

We found the use of edge habitat to be disproportionate to the availability of edge and associated with forest cover (fig. 6). The model indicates that bears seek the edge ecotone but remain in cover. This finding is supported by the work of Blanchard (1980).

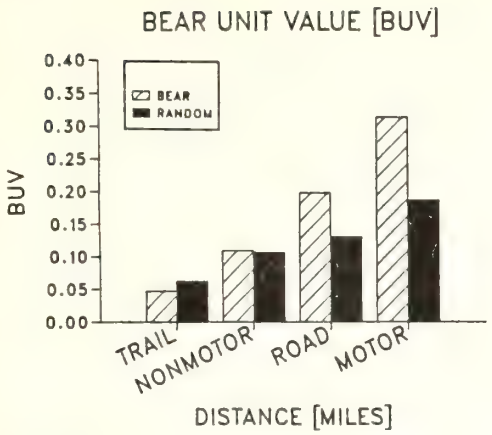


Figure 3.--Cartographic model validation calculation of bear unit values (BUV) for random and grizzly bear radio locations associated with selected displacement coefficients in the Pilot Peak area. Bear unit value = bear use disproportionately associated with higher quality habitat. Value increases with increasing size of area.

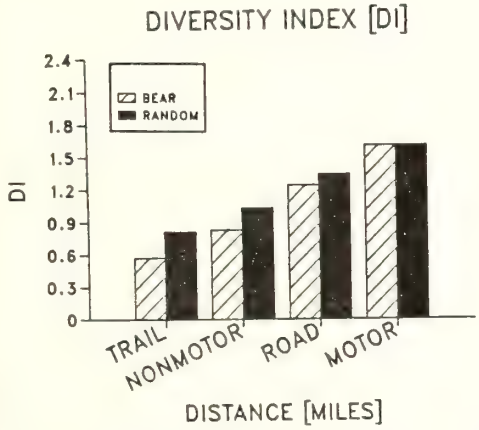


Figure 4.--Cartographic model validation calculation of diversity indices (DI) for random and grizzly bear radio locations associated with selected displacement coefficients in the Pilot Peak area. Diversity index = area size dependent. Emphasis exaggerated in model.

Coefficient Values

We found habitat coefficient values associated with the proportional use of habitat cover types within the zones of influence were disproportionate and did not always correspond to the magnitude of the habitat coefficients (fig. 7). For example, the proportions of moist, high, and dry grasslands (coefficients of 0.293, 0.001, 0.001, respectively) did not follow the expected trend of use. This suggests that habitat values within the model should be more responsive to seasonal activity patterns and juxtaposition of vegetation polygons. A three-dimensional function that incorporates time, space, and habitat value might be more appropriate than the current two-dimensional array of coefficient values.

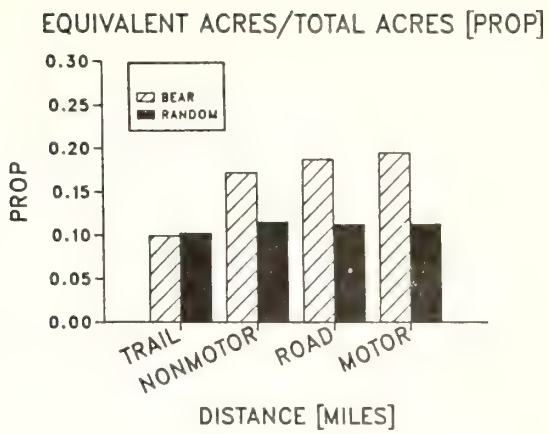


Figure 5.--Cartographic model validation calculations of equivalent acres/total acres (PROP) for random and grizzly bear radio locations associated with selected displacement coefficients in the Pilot Peak area. Equivalent acres/total acres = the most reliable indicator of habitat quality.

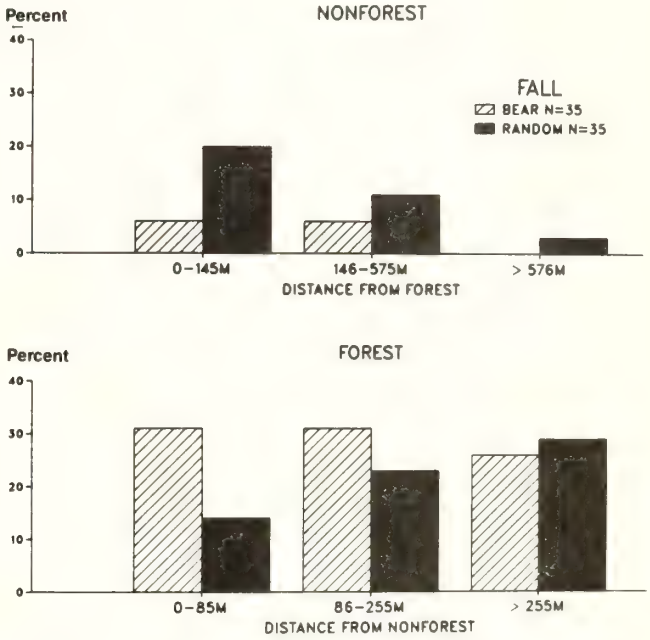


Figure 6.--Edge relationships of random and fall grizzly bear radio locations in forested and nonforested habitats in the Pilot Peak area.

MANAGEMENT IMPLICATIONS

Our findings fall into two general areas: First, it appears that the application of cartographic models within the decision-making process provides for:

1. The simulation and evaluation of a series of management strategies.

2. Dealing with the spatial relationships, juxtaposition, and diversity.

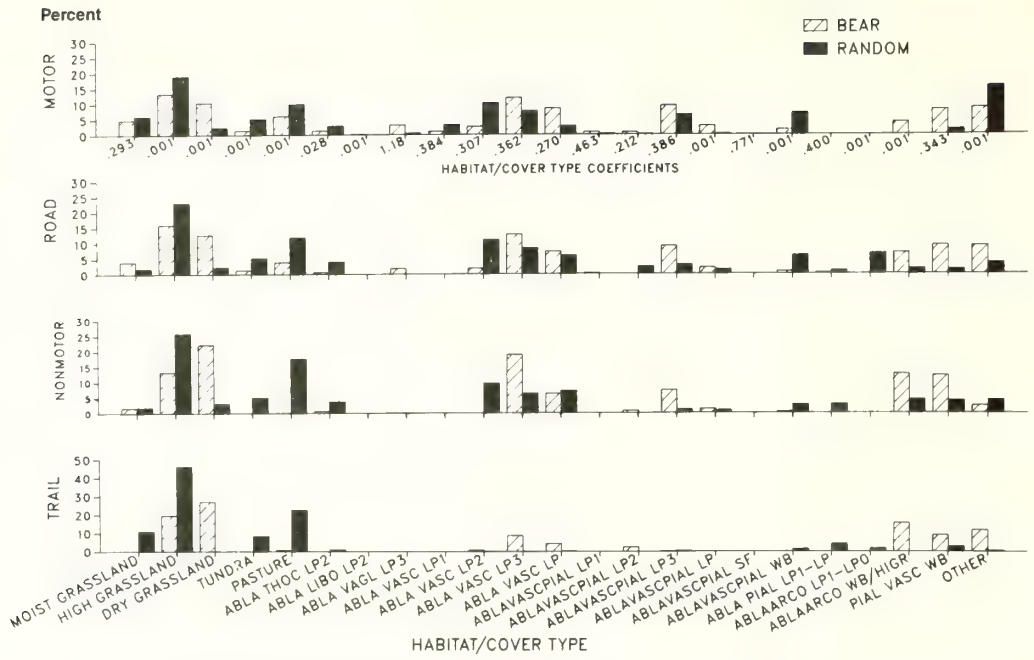


Figure 7. Proportions of habitat types included in zones of influence calculated for four displacement coefficients associated with random and fall grizzly bear radio locations in the Pilot Peak area.

3. Identifying precise areas with management opportunities.

4. Integrating other species into the analysis process.

Second, we have outlined a process that uses cartographic simulations to validate cumulative effects assumptions. This process includes:

1. Outlining the assumptions in detail.

2. Defining the rule set.

3. Organizing the data base.

4. Testing or validating the rule set.

We see a need for a stringent peer review of the model's basic assumptions, the level of accuracy required by the vegetation data base, and rule set validation.

In conclusion, our task was simple--merely to review and synthesize the work of others. It is our colleagues, who seized the opportunity and developed the initial rule sets for cumulative effects models, who are to be commended. We salute their collective and individual courage and effort; however, we should not lose sight of the paramount goal: our commitment as land managers to share the ecosystem with the great bear.

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Contreras, Glen P.; Evans, Keith, E., compilers. Proceedings—grizzly bear habitat symposium. 1985 April 30-May 2; Missoula, MT. General Technical Report INT-207. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 252 p.

Contains 33 papers and three abstracts including state-of-the-art information on grizzly bear habitat delineation and management. Topics are general habitat concerns, considerations, and conditions; mapping and evaluation; habitat improvement and coordination; and cumulative effects of activities on habitat.

KEYWORDS: *Ursus arctos*, threatened and endangered species, habitat research, habitat mapping, habitat evaluation, ecosystem analysis, cumulative effects.

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Intermountain
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General Technical
Report INT-208

July 1986

Supplement to the User's Guide for the Stand Prognosis Model—Version 5.0

William R. Wykoff

$$CR=f_e[CCF\cdot\cdot]$$

$$B=\frac{1}{\sqrt{2\pi}}\int_a^b Xe^{-X^2/2}dX$$

$$\ln[\Delta H]=f_N[\Delta D,H,D]$$

$$MORT=\frac{1}{1+\exp[-B_iX_i]}$$

$$\ln[BAI]=f_B[D.b.h.,Habitat,Crown]$$



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RESEARCH SUMMARY

Version 4.0 of the Prognosis Model was released in September 1981. Since then, a regeneration establishment model has been completed and small-tree increment models have been greatly refined. The COVER model has also been added to predict shrub development and total canopy cover. Thus, the representation of the vegetative component of the stand is basically complete and the Stand Prognosis Model can be linked more readily to models for nontimber resources.

New management options have been added to the system, and an Event Monitor increases the flexibility for scheduling management activities. A compression or classification algorithm enhances program efficiency by combining tree records that are similar with regard to attributes that influence growth predictions. Finally, there have been numerous improvements in the biological models.

This report is a supplement to the user's guide for the Stand Prognosis Model (Wykoff and others 1982). Options that were available in version 4.0 may still be invoked in the manner described in the user's guide. New options, new models, and modifications to existing models are herein described as incorporated in version 5.0.

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July 1986
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Supplement to the User's Guide for the Stand Prognosis Model—Version 5.0

William R. Wykoff

INTRODUCTION

Version 5.0 of the Prognosis Model for Stand Development (Stage 1973) was released in July 1984. This version contains many enhancements that follow the release of version 4.0 in September 1981 (Wykoff and others 1982). Biological models were reformulated to correct apparent deficiencies, and submodel parameters were reestimated to take advantage of new data. Options have been added to increase the scope of the program and ease user interaction. In addition, several new extensions have been developed.

In order to maintain a semblance of stability for program users, very few of these changes were incorporated into version 4.0. (Copies of version 4.0 source code were distributed to 29 public and private organizations.) Programming and model formulation errors were corrected and distributed, but version 4.0 produces essentially the same results today that it did when first released.

Developments from the period 1981 through 1984 have been implemented in Prognosis Model version 5.0. These developments include:

- Revision of the small-tree height increment model and the large-tree d.b.h. increment model.

- Replacement of the small-tree d.b.h. increment model, the mortality model, and the crown dubbing procedure.

- Replacement of the procedure for calibrating the large-tree d.b.h. increment and small-tree height increment models so that the average predicted increment matches the average observed increment, regardless of sampling design.

- Modifications to the DESIGN, and THINning options that increase program flexibility.

- Introduction of new options such as NOTREES, HTGSTOP, TOPKILL, COMPRESS, and an Event Monitor.

- Linkages to a western spruce budworm model, a regeneration establishment model, COVER, and a parallel processor.

This supplement to the User's Guide describes differences in the behavior of biological models, provides reference information on using new extensions, and describes new options and modifications to existing options. Benchmarking procedures and results of test runs, including comparisons with version 4.0, will be reported separately. These benchmarks will provide a mechanism for the systematic evaluation of future model changes.

CHANGES IN PREDICTIONS OF TREE DEVELOPMENT

Version 5.0 retains two of the five submodels that were part of version 4.0 (the large-tree height increment and crown change models). Three submodels have been modified or replaced (the mortality model, the small-tree height increment model, and the large-tree d.b.h. increment model). In addition, new models

for predicting d.b.h. increment and crown change in small trees (d.b.h. < 3.0 inches) were implemented. New models and modifications are briefly described below. Coefficients are listed for the models that differ from version 4.0 formulations.

Small-Tree Models

Small-tree growth has been modified considerably by changes in the mechanisms for prediction of height increment, d.b.h. increment, and change in crown ratio. The small-tree height increment model (eq. 1) now includes relative tree size effects and has been expanded to apply to additional habitat types. These effects were borrowed from the large-tree d.b.h. increment model that is part of version 4.0 (Wykoff and others 1982). For trees with d.b.h. less than 2 inches, the height increment prediction is based entirely on equation 1. For trees between 2 and 10 inches d.b.h., small- and large-tree height increment predictions are averaged as described for version 4.0.

$$\ln(HTG_2) = HAB + LOC + 0.22157 \cdot SL \cdot \cos(ASP) - 0.12432 \cdot SL \cdot \sin(ASP) - 0.10987 \cdot SL + b_1 \cdot \ln(HT) + b_2 \cdot CCF + b_3 \cdot (BAL/100) \quad (1)$$

where:

HTG_2 = height increment prediction for trees with d.b.h. less than 3 inches.
HAB = constant term (intercept) that is dependent on habitat type.
LOC = constant term (intercept) that is dependent on location.
ASP = stand aspect (degrees).
SL = stand slope ratio (%/100).
HT = tree height (ft).
CCF = crown competition factor.
BAL = basal area in larger trees (ft^2/acre).
b_1, b_2, b_3 = regression coefficients that are dependent on species (see tables 1 and 2).

Table 1.—Coefficients for the small tree height increment model (see equation 1)

Variable		Species[1]										
		WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
ln(HT)	(b_1)	0.4214	0.2716	0.3907	0.3487	0.3417	0.2354	0.5843	0.2827	0.3740	0.4485	0.235
CCF	(b_2)	−.0059	−.0065	−.0059	−.0039	−.0039	−.0039	−.0065	−.0039	−.0039	−.0065	−.003
BAL/100	(b_3)	−.3720	−.4153	−.4004	−.2536	−.3469	−.1201	−.2417	−.2530	−.2296	−.4730	−.253
Habitat	1	1.2554	1.4058	1.2786	.7835	.8056	.6807	1.0190	.8818	.8521	1.5165	.680
class	2	1.3759	1.5263	1.3991	.9040	.9261	.8012	1.1392	1.0023	.9726	1.6370	.801
constants	3	1.1559	1.2908	.9531	.7205	1.0202	.8953	.9852	.7533	.5751	1.2966	.521
(HAB)[2]	4	1.4700	1.6204	1.0984	.9981			.7202		.7085	1.7311	.895
	5			1.4932				.8841		1.0667		
	6							1.2336				
Location	1	0.0										
class	2	−.0480	same for all species									
constants	3	−.2785										
(LOC)[3]												

[1]Species codes are defined in appendix A, table 14.
[2]Habitat classes are defined in table 2.
[3]Location classes:
1 Clearwater and Nezperce National Forests
2 St. Joe and Coeur d'Alene National Forests
3 All other Forests.

Table 2.—Index by species to habitat class constants for the small tree height increment model (see equation 1)

Habitat code[1]	Species[1]										
	WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
130	3	3	4	3	1	1	5	1	4	1	3
170	3	3	4	3	1	1	5	1	4	1	3
250	3	3	4	3	1	1	5	1	4	1	3
260	3	3	4	3	1	1	5	1	4	3	3
280	3	3	4	3	1	1	1	1	4	3	3
290	3	3	4	3	1	1	1	1	4	1	3
310	3	3	4	3	1	1	1	1	4	1	3
320	3	3	1	3	1	1	5	1	4	3	3
330	3	3	4	3	1	1	5	1	4	3	3
420	3	1	4	3	1	1	5	1	4	3	3
470	3	1	4	3	1	1	5	1	4	3	3
510	3	1	1	3	1	1	1	1	4	1	3
520	1	1	1	1	1	1	1	1	1	1	1
530	2	2	2	2	2	2	2	2	2	2	2
550	4	4	5	4	3	3	6	4	5	4	4
570	4	4	5	4	3	3	6	4	5	4	4
610	4	4	5	4	3	3	6	4	5	4	4
620	1	1	1	1	1	1	6	1	1	1	1
640	3	3	4	3	1	1	4	1	4	3	3
660	3	3	3	3	1	1	4	1	4	3	3
670	3	3	4	1	1	1	3	1	4	3	2
680	3	3	4	1	1	1	4	1	4	3	3
690	3	3	4	3	1	1	5	1	4	3	3
710	3	3	4	3	1	1	5	1	4	3	3
720	3	3	4	3	1	1	4	1	1	3	3
730	3	3	4	3	1	1	4	1	1	3	3
830	3	3	3	3	1	1	4	3	3	3	3
850	3	3	4	3	1	1	5	1	3	3	3
999	3	3	4	3	1	1	5	1	4	3	3

Habitat and species codes are defined in appendix A, tables 13 and 14.

In addition, the strategy for predicting diameter increments for small trees was changed. In version 4.0, the large-tree d.b.h. increment model is applied to small trees with the frequent result that trees with unusual proportions are generated (usually, large heights with small d.b.h.'s). The new model is applied only to trees with d.b.h. less than 3 inches, and it predicts d.b.h. directly from height with adjustments for stand density and relative size (eq. 2). The adjustments were developed by analyzing prediction errors from a white pine spacing study in Deception Creek Experimental Forest near Coeur d'Alene, ID.

$$DBH = b_0(HT-4.5)^{b_1} + \left[\frac{AVH}{36}(0.01232 \cdot CCF - 1.75) \cdot RELH\right] \cdot (RELH - 2.0) + 0.65 \qquad (2)$$

where:

DBH = diameter at breast height.

AVH = average height of the 40 trees per acre with the largest d.b.h.'s (top height).

RELH = relative height = $(HT-4.5)/(AVH-4.5)$ $(0 \leq RELH \leq 1.0)$.

b_0, b_1 = regression coefficients that are dependent on species (see table 3).

Finally, the procedure for assigning crown ratio (CR) to small trees was replaced. The new model is based on the logistic equation and predictions are dependent on tree height, tree d.b.h., and stand basal area (eq. 3). Parameters

Table 3.—Coefficients for the model used to predict d.b.h. (inches) for small trees (see equation 2)

Species	b_0	b_1
Western white pine	0.0781	1.1645
Western larch	.0751	1.1176
Douglas-fir	.0828	1.1713
Grand fir	.1155	1.0688
Western hemlock	.0729	1.1988
Western redcedar	.0730	1.2343
Lodgepole pine	.0988	1.0807
Engelmann spruce	.0658	1.3817
Subalpine fir	.0658	1.3817
Ponderosa pine	.2160	1.0049
Mountain hemlock	.0729	1.1988

Table 4.—Coefficients for the model used to assign crown ratio to small trees (see equation 3)

Species	b_0	b_1	b_2	b_3
Western white pine	−0.4432	−0.4845	0.0582	0.00513
Western larch	−.8396	−.1611	.0416	.00602
Douglas-fir	−.8912	−.1808	.0519	.00454
Grand fir	−.6265	−.0614	.0236	.00505
Western hemlock	−.4955	.0	.0036	.00456
Western redcedar	.1185	−.3931	.0278	.00626
Lodgepole pine	−.3247	−.2011	.0422	.00436
Engelmann spruce	−.9201	−.2245	.0325	.00620
Subalpine fir	−.8901	−.1803	.0223	.00614
Ponderosa pine	−.1756	−.3385	.0570	.00692
Mountain hemlock	−.4955	.0	.0036	.00456

were estimated from the data used to develop the small-tree height increment model. For most species, CR increases with increasing d.b.h. and decreases wit increasing HT or BA. Western and mountain hemlock, however, are insensitive to changes in d.b.h.

$$CR = \frac{1}{1 + \exp(b_0 + b_1 \cdot DBH + b_2 \cdot HT + b_3 \cdot BA)}$$

where:

BA = stand basal area (ft^2/acre).

b_0, b_1, b_2, b_3 = regression coefficients that are dependent on species (see table 4).

If the inventory does not include some or all crown ratio measurements, this model is used to assign CR for input tree records that are less than 3 inches d.b.h. The model is also used to assign a new CR during the cycle in which the tree attains a 3-inch d.b.h. Thereafter, CR change is predicted as in version 4.

Crown ratio does not influence small tree growth predictions and, therefore, no periodic change is simulated. Missing input values are dubbed to provide consistency in program output and to facilitate operation of Prognosis Model extensions such as COVER and the Douglas-fir tussock moth model.

As a result of model changes, predictions of height and d.b.h. increment are sensitive to both relative tree size and overall stand density (fig. 1). This system of models has demonstrated reasonable behavior in tests to date although comparisons with data from larch spacing studies (Milner 1985) show clear

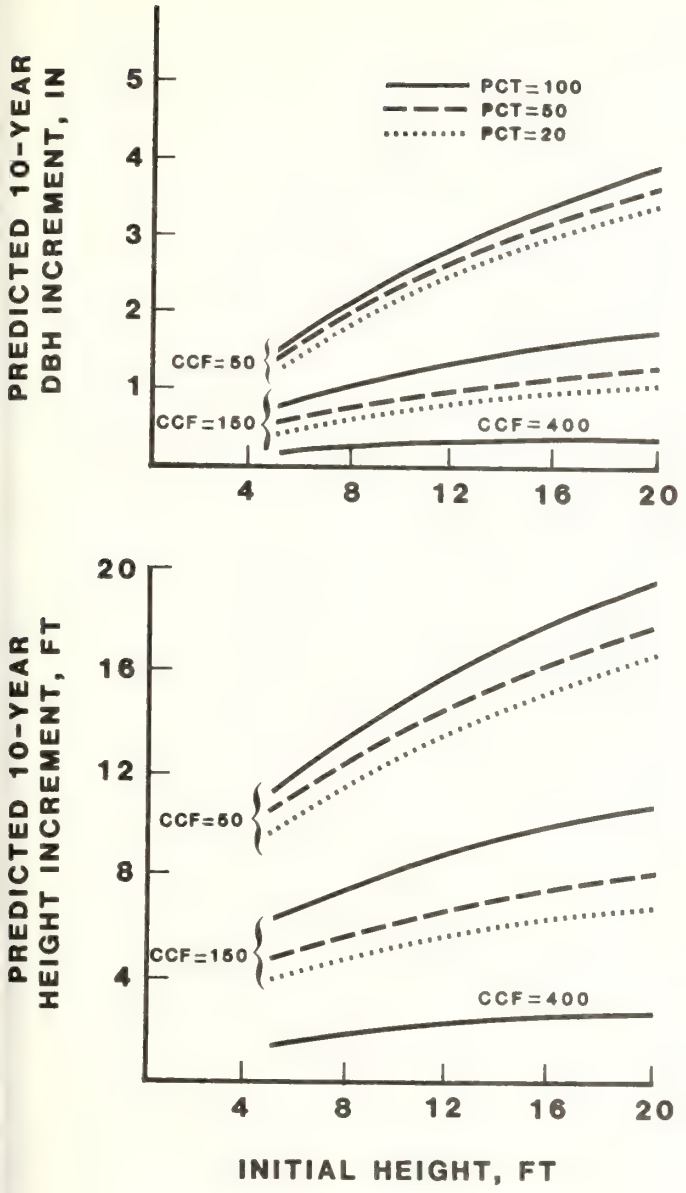


Figure 1.—Height and diameter increment predictions for small trees are sensitive to social position (as indicated by percentile in the basal area distribution, PCT) and to overall stand density (crown competition factor, CCF). Curves shown are for Douglas-fir growing on a western redcedar/*Clintonia* habitat type at 3,700 ft elevation in the Clearwater National Forest.

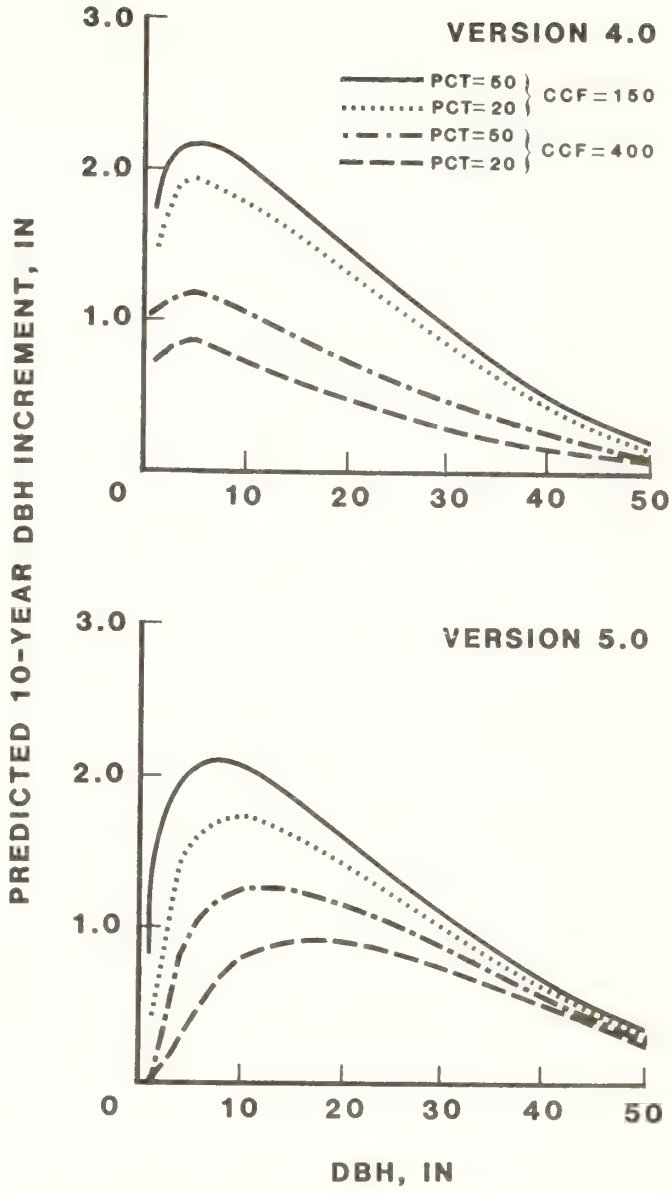


Figure 2.—The most notable differences in large-tree d.b.h. increment predictions are for subordinate trees growing in dense stands. As stand density increases, and as percentile in the basal area distribution decreases, the maximum in the increment curve shifts downward to correspond with larger d.b.h. Conditions displayed are identical to those displayed in Wykoff and others (1982; fig. 29, p. 63).

trends in prediction errors for both height and d.b.h. increment relative to initial spacing. Many of the relationships are based on crude analyses or limited data or both, and the system is at best tenuous. Work is currently underway to further refine the prediction of small tree growth.

D.b.h. Increment for Large Trees

Two changes were made in the version 5.0 large-tree d.b.h. increment model (d.b.h. $\geq$ 3 inches). The ratio, BAL/ln(DBH + 1) allows the magnitude of the relative size effect to vary with d.b.h. In addition, the CCF coefficients vary by habitat class. As a result of these changes, the model is less sensitive to changing d.b.h. and more sensitive to stand density and relative size (fig. 2).

$$\ln(dds) = HAB + LOC + b_1 \cdot SL \cdot \cos(ASP) + b_2 \cdot SL \cdot \sin(ASP) + b_3 \cdot SL + b_4 \cdot SL^2 + b_5 \cdot EL + b_6 \cdot EL^2 + b_7 \cdot \ln(DBH) + b_8 \cdot CR + b_9 \cdot CR^2 + b_{10} \cdot (BAL/100) + b_{11} \cdot BAL/\ln(DBH + 1) + b_{12} \cdot DBH^2 + b_{13} \cdot (CCF/100) \quad (4)$$

where:

dds = 10-year change in squared d.b.h.

EL = stand elevation (in hundreds of feet).

CR = ratio of crown length to total tree height.

b_1 through b_{13} = regression coefficients that are dependent on species, b_{12} is dependent on location, and b_{13} is dependent on habitat type (see tables 5, 6, 7, 8, and 9).

Table 5.—Coefficients for the large-tree d.b.h. increment model (see equation 4)

Variables (classes)		Species[1]										
		WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
Habitat	1	1.1558	0.3834	0.4778	0.6676	0.4526	1.6145	0.7740	−0.5884	−0.9639	1.1623	−1.68
class	2	1.0564	.5129	.1523	.6045		1.3177	.6783	−.2124	−.7242	.7341	−1.52
constants	3		.4538	.2976				.6445	−.7163	−.5731	.5142	
$(HAB)^2$	4		.7132					.3794	−.5395	−.8222		
	5		.2684					.5434		−1.2409		
	6									−1.1075		
Location	1	.1692	.2000	.5036	.4344	.1067	.5007	.4374	.2626	.4206	.2459	.12
class	2	.0	.0766	.3492	.2834	.4436	.1765	.2111	−.1587	.1407	.5696	.48
constants	3		.0819	.2196	−.1483	.0	.3174	.1481	.0	−.1300	.4279	.0
$(LOC)^3$	4		.3038	.6181	.2020		.0	.0		.0	.0	
	5		.0	.0	.5776							
	6				.0							
SL•Cos(ASP)	(b_1)	.0982	−.2134	−.0456	−.0122	.0828	−.0662	.0032	−.1309	−.1247	−.0998	.17
SL•Sin(ASP)	(b_2)	.0388	.0343	.0629	−.0460	.1099	.0553	.1299	−.0604	−.0686	.0119	.13
SL	(b_3)	−.1789	.3352	.7818	1.1702	.0497	.1193	.4655	.6562	.3007	−.0664	.07
SL^2	(b_4)	.0	−.7022	−1.1238	−1.5201	.0	.0	−.5801	−.9014	−.6222	−.4372	.0
EL	(b_5)	.0352	.0373	.0259	.0092	.0286	−.0018	−.0048	.0626	.0631	.0323	.08
EL^2	(b_6)	−.00047	−.00043	−.00038	−.00012	−.00042	−.00007	−.00006	−.00071	−.00068	−.00042	−.00
ln(DBH)	(b_7)	.5644	.5414	.5689	.6881	.6871	.5870	.8950	.7304	.8624	.6610	.89
CR	(b_8)	1.0834	1.0348	2.0685	1.9397	1.6413	1.2936	1.8556	1.5464	.5204	1.3162	1.28
CR^2	(b_9)	.0	.0751	−.6236	−.7826	−.2724	.0	−.3639	−.2664	.8624	.0	.0
BAL/100	(b_{10})	.4211	.4364	.5020	.4514	.0	.7460	−.0366	.2564	.0	.0	.0
BAL/ln(DBH + 1)	(b_{11})	−2.0827	−2.0326	−2.1159	−1.7681	−.8092	−2.2838	−.4333	−1.1822	−.5127	−1.2588	−.66
DBH^2	1	−.00044	−.00031	−.00025	−.00027	−.00022	.0	−.00126	−.00013	−.00028	−.00041	−.00
classes	2	.0	−.00057	−.00037	−.00009	−.00043		−.00217	−.00029	−.00078	−.00044	−.00
$(b_{12})^4$	3			−.00050	−.00064			−.00189	−.00043		−.00014	
	4			−.00057				−.00087				
CCF	1	−.0243	−.1014	−.0905	−.0962	.0	−.0505	−.0558	−.0155	−.0160	−.1042	−.1
classes	2	−.2489	−.1479	−.1188	−.1954		−.1536	−.1492	−.3839	−.0448	−.8881	
$(b_{13})^5$	3	−.0108	−.0544	−.0553	−.0512		−.0940	−.4064	−.0537	−.0739	−.2594	
	4			−.0218				−.1140	−.1516		−.1473	

[1]Species codes are defined in appendix A, table 14.
[2]Habitat classes are defined in table 6.
[3]Location classes are defined in table 7.
[4]DBH-squared classes are defined in table 8.
[5]CCF classes are defined in table 9.

Table 6.—Index by species for the habitat constants in the large-tree d.b.h. increment model (see equation 4)

Habitat code[1]	Species[1]										
	WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
130	2	5	3	2	1	2	5	4	6	1	2
170	2	5	3	2	1	2	5	4	6	1	2
250	2	5	3	2	1	2	5	4	6	2	2
260	2	5	3	2	1	2	5	4	6	3	2
280	2	5	3	2	1	2	1	4	6	3	2
290	2	5	3	2	1	2	2	4	6	2	2
310	2	5	3	2	1	2	1	4	6	2	2
320	2	5	1	2	1	2	5	4	6	3	2
330	2	5	3	2	1	2	5	4	6	3	2
420	2	1	3	2	1	2	5	4	6	3	2
470	2	1	3	2	1	2	5	4	6	3	2
510	2	2	1	2	1	2	2	1	6	2	2
520	1	1	1	1	1	2	2	1	1	2	2
530	1	2	1	2	1	2	3	4	2	2	2
550	1	3	1	2	1	1	3	2	3	1	2
570	1	3	1	2	1	2	3	4	4	1	2
610	1	3	1	2	1	2	3	2	3	1	2
620	1	2	1	2	1	2	3	1	1	3	2
640	2	5	3	2	1	2	4	4	6	3	2
660	2	2	2	2	1	2	4	4	6	3	2
670	1	1	3	1	1	1	3	4	6	3	1
680	1	1	3	2	1	2	4	4	6	3	2
690	2	1	3	2	1	2	5	4	6	3	2
710	2	5	3	1	1	2	5	4	6	3	2
720	2	4	3	2	1	2	4	4	1	3	2
730	2	4	3	2	1	2	4	4	1	3	2
830	2	5	2	2	1	2	4	3	5	3	2
850	2	5	3	2	1	2	5	4	5	3	2
999[2]	2	5	3	2	1	2	5	4	6	3	2

[1]Habitat and species codes are defined in appendix A, tables 13 and 14.
[2]Types grouped with 999 were included in the overall mean for the species.

Table 7.—Index by species for the location constants in the large-tree d.b.h. increment model (see equation 4)

National Forest	Species[1]										
	WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
Bitterroot	2	1	5	6	3	4	4	3	4	1	3
Clearwater	2	1	1	1	3	1	1	1	1	2	1
Coeur d'Alene	2	2	2	2	1	1	1	1	2	2	1
Colville	2	3	3	2	3	2	2	3	2	1	3
Flathead	2	3	3	3	3	2	4	2	3	4	3
Kaniksu	2	2	2	2	3	3	3	3	3	3	3
Kootenai	2	5	3	4	3	4	3	3	4	1	3
Lolo	2	5	5	6	3	2	4	3	4	4	1
Nezperce	2	4	1	2	3	1	2	1	2	3	3
St. Joe	1	1	4	5	2	1	2	1	1	2	2

[1]Species codes are defined in appendix A, table 14.

Table 8.—Index by species for the location-dependent DBH-squared coefficients in the large-tree d.b.h. increment model (see equation 4)

National Forest	Species[1]										
	WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
Bitterroot	1	1	1	1	1	1	1	1	1	1	1
Clearwater	2	1	2	1	1	2	2	2	2	2	1
Coeur d'Alene	2	1	2	1	1	1	2	1	1	2	1
Colville	2	1	2	1	2	1	1	1	2	2	1
Flathead	1	1	3	2	1	1	1	1	1	3	1
Kaniksu	2	1	1	2	1	1	2	3	1	3	1
Kootenai	1	1	4	3	1	2	3	2	2	2	1
Lolo	1	1	1	1	1	1	1	1	1	1	2
Nezperce	1	1	1	2	1	2	4	1	1	1	1
St. Joe	2	2	4	1	2	1	1	1	2	2	2

[1]Species codes are defined in appendix A, table 14.

Table 9.—Index by species for the habitat-dependent CCF coefficients in the large-tree d.b.h. increment model (see equation 4)

Habitat code[1]	Species[1]										
	WP	L	DF	GF	WH	C	LP	S	AF	PP	MH
130	3	3	4	3	1	3	4	4	3	2	1
170	3	3	4	3	1	3	4	4	3	2	1
250	3	3	4	3	1	3	1	4	3	3	1
260	3	3	4	3	1	3	4	4	3	1	1
280	3	3	4	3	1	3	3	4	3	4	1
290	3	3	4	3	1	3	4	4	3	3	1
310	3	3	1	3	1	3	2	4	3	3	1
320	3	3	2	3	1	3	1	4	3	1	1
330	3	3	4	3	1	3	4	4	3	2	1
420	3	3	4	3	1	3	1	4	3	4	1
470	3	3	4	3	1	3	4	4	3	4	1
510	3	3	2	3	1	3	4	3	3	1	1
520	1	1	1	1	1	3	4	3	1	4	1
530	3	3	4	3	1	1	2	1	1	4	1
550	3	3	4	3	1	2	2	1	1	4	1
570	1	3	3	3	1	3	2	3	1	1	1
610	3	3	4	3	1	3	2	3	1	4	1
620	3	2	4	3	1	2	2	1	1	4	1
640	3	3	4	3	1	3	4	4	3	4	1
660	3	1	1	3	1	3	1	2	1	4	1
670	2	3	3	3	1	1	4	4	1	4	1
680	2	3	2	3	1	3	1	1	2	4	1
690	3	1	4	2	1	3	4	4	2	4	1
710	3	1	4	2	1	3	4	4	1	4	1
720	3	3	4	3	1	3	1	1	1	4	1
730	3	3	4	3	1	3	1	1	1	4	1
830	3	3	2	3	1	3	4	4	1	4	1
850	3	3	4	3	1	3	4	4	3	4	1
999	3	3	4	3	1	3	4	4	3	4	1

[1]Habitat and species codes are defined in appendix A, tables 13 and 14.

Individual Tree Mortality Models

The mortality model now incorporates explicit terms that reflect stand density and tree vigor. In version 4.0, mortality rate was predicted from a regression model, with DBH and DBH^2 used as independent variables. Then, various correction factors were applied to reflect the effect of stand density. The correction factors were derived from yield tables (Haig 1932), published data on carrying capacities of various habitat types (Pfister and others 1977; Daubenmire and Daubenmire 1968), analysis of Northern Region timber management planning inventories, and "best guesses." The stand level models were required because the data used to develop the individual tree models contained limited information on stand density and relative size, and these effects were therefore absent from the final model.

The mortality model used in version 5.0 uses rate estimates (R_a and R_b) that are predicted from two independent equations. R_a (eq. 5) is based primarily on the analysis of permanent sample plots that are maintained by the Intermountain Station (Hamilton in preparation a). Predictions are dependent on habitat type, species, d.b.h., d.b.h. increment, estimated potential d.b.h. increment, stand basal area, and relative diameter (d.b.h./mean stand d.b.h.).

$$R_a = \{1 + \exp[b_0 + b_1 \cdot \sqrt{DBH} + b_2 \cdot \sqrt{BA} + b_3 \cdot g + b_4 \cdot RDBH + (b_5 + b_6 \cdot g) \cdot DBH^{-1}]\}^{-1} \quad (5)$$

where:

R_a = estimated annual mortality rate.

g = periodic annual d.b.h. increment for previous growth period adjusted for differences in potential annual d.b.h. increment indexed by habitat type and National Forest.

RDBH = the ratio of tree d.b.h. to the arithmetic mean stand d.b.h.

b_0 = species dependent constant (see table 10).

b_1 = 0.2223

b_2 = −0.0460

b_3 = 10.0810

b_4 = 0.2463

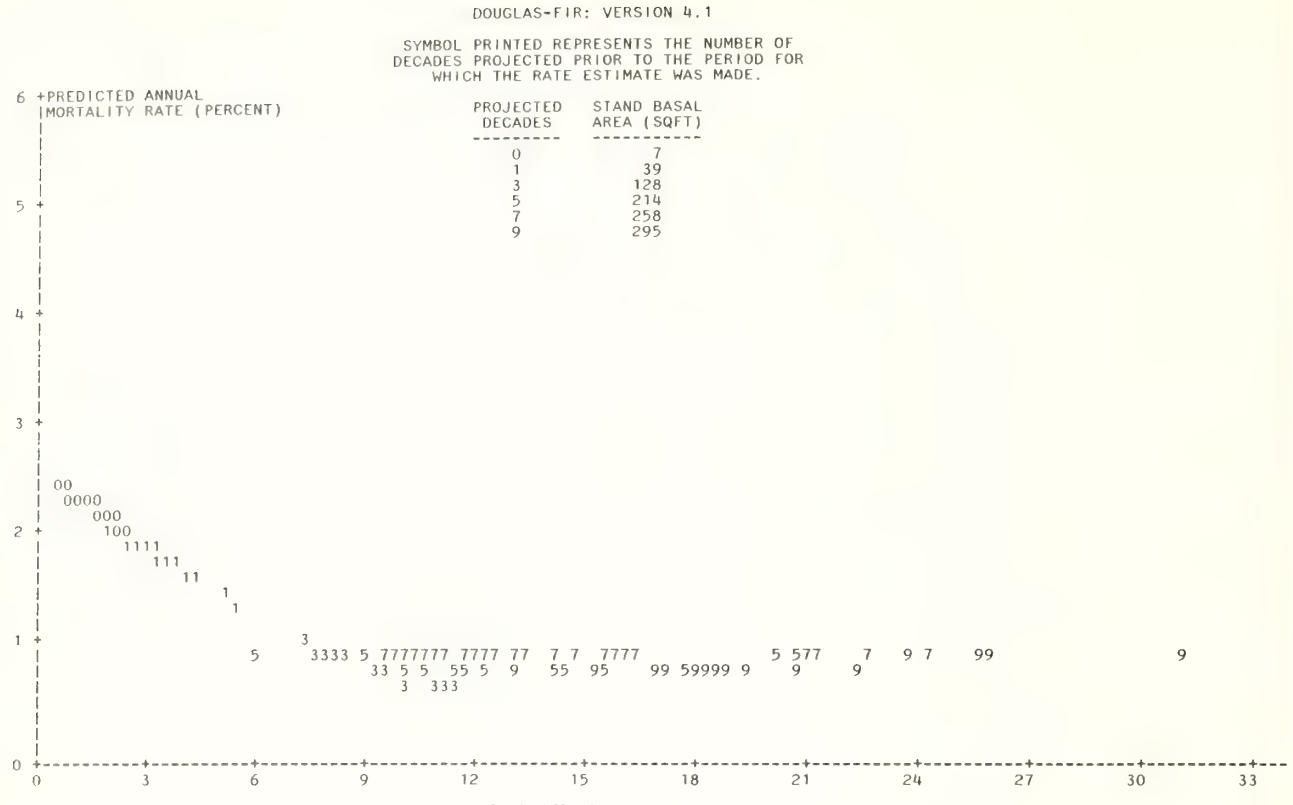
b_5 = −0.5544

b_6 = 6.0713.

R_a is multiplied by a factor based on Reineke's (1933) Stand Density Index that accounts for expected differences in mortality rates on different habitat types and National Forests (Hamilton in preparation b).

Table 10.—Species-dependent constants for the mortality model (see equation 9)

Species	Constant (b_0)
Western white pine	0.0
Western larch	−.1760
Douglas-fir	.3179
Grand fir	.3179
Western hemlock	.6077
Western redcedar	1.5798
Lodgepole pine	−.1206
Engelmann spruce	.9402
Subalpine fir	.2118
Ponderosa pine	.2118
Mountain hemlock	.0



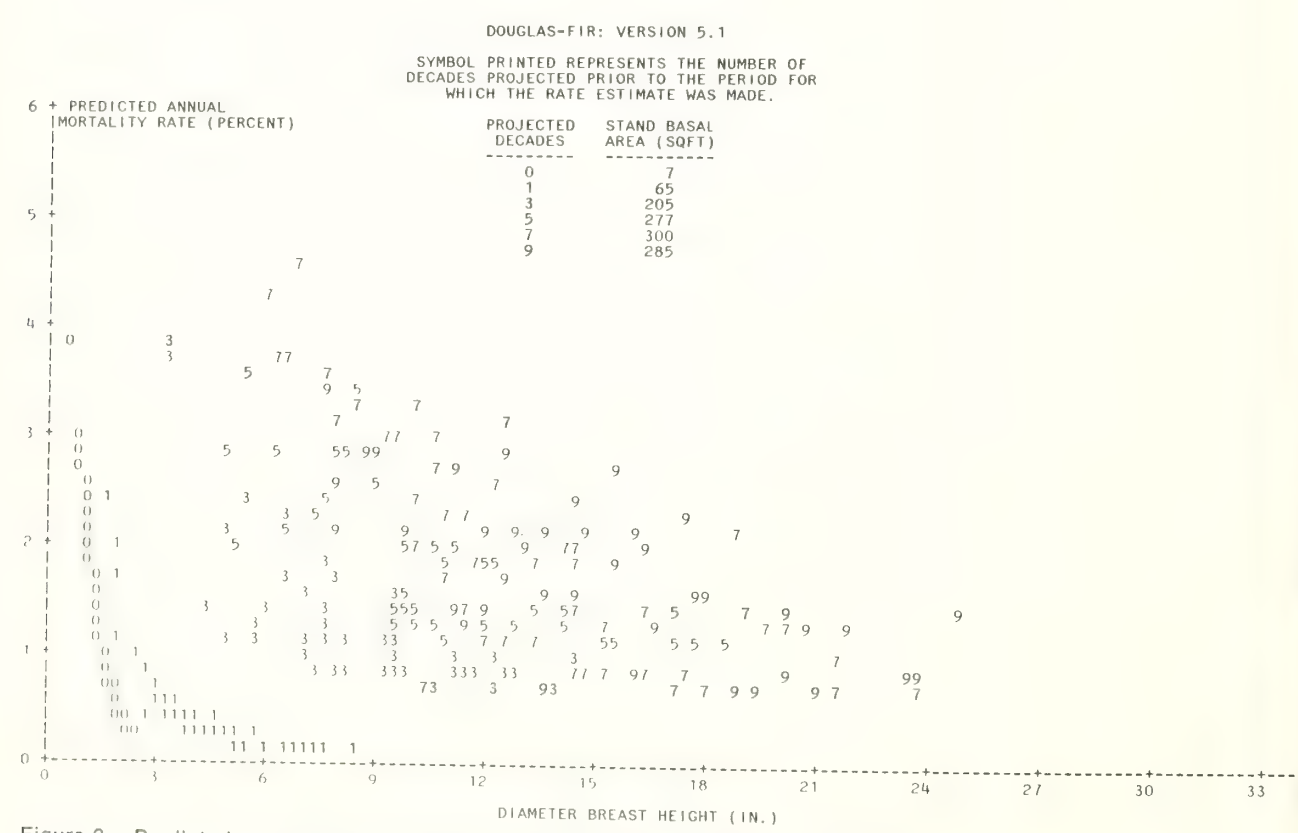


Figure 3.—Predicted annual mortality rate versus d.b.h. for Douglas-fir. The numbers printed represent decades in a long-term projection (1 is the average rate for years 11-20 in the projection; 9 is the average rate for years 90-100 in the projection). Initial stand and site conditions are the same as for figure 1. Figure 3a displays rates projected by version 4.1; figure 3b displays rates projected by version 5.1.

For purposes of predicting mortality rate, d.b.h. and d.b.h. increment are bounded. If d.b.h. is less than 0.5 inch, it is set equal to 0.5 inch; if d.b.h. is less than 1 inch and d.b.h. increment is less than 0.05 inch, d.b.h. increment is set to 0.05 inch.

The second part of the mortality rate estimate, R_b, is dependent on the proximity of stand basal area to the assumed maximum for a site (BAMAX) and on the estimated rate of basal area increment. As stand basal area approaches BAMAX, R_b approaches 1. The calculation of R_b is described by Wykoff and others (1982). As in version 4.0, the value of BAMAX is indexed to habitat type, but the default value may be overridden by the user.

The mortality rate actually applied to a tree is a weighted average of R_a and R_b. The weights applied to the respective estimates are also dependent on the proximity of stand basal area to BAMAX (eq. 6).

$$R_t = W \cdot R_b + (1-W) \cdot R_a \quad (6)$$

where:

R_t = annual mortality rate applied to tree t.
W = BA/BAMAX.

In general, the new mortality model is more sensitive to stand density and to the distribution of size classes (fig. 3) and better reflects the relationships between stand dynamics and management.

Random Effects

In application, random errors are drawn and attached to predictions of large-tree d.b.h. increment, small-tree height increment, and small-tree crown ratio. For all of these variables, the error is assumed to be Normally distributed when the model is transformed so that it is linear in the parameters. The random error is drawn from a Normal distribution on the transformed scale. Random effects are propagated in other models by including d.b.h., crown ratio, or height increment or all three as independent variables.

Interpretation of Input Stockability Data

When nonstockable plots are encountered in a stand inventory, their ratio to total plots is taken to represent the proportion of total stand area that is uninhabitable by trees. In version 4.0, only the value of crown competition factor is adjusted to reflect stockability, resulting in an inconsistent representation of density effects in the increment models. In version 5.0, the stand area used to compute the trees per acre represented by each sample tree is based only on stockable plots. As a result, all stand and tree attributes carried by the program represent stockable area. As described in the section titled "Changes in Program Output," the program output now reports stand attributes on the basis of both total and stockable area.

Calibration of Growth Models

In version 5.0, there is a new procedure for using input growth data to adjust the large-tree d.b.h. increment and small-tree height increment models. The new procedure is designed to eliminate a bias that occurred in version 4.0 when all sample trees were measured for increment. Predictions are made for each growth-sample tree and then observed increment (g_o) is regressed against predicted increment (g_p):

$$g_o = a + b \cdot g_p$$

A prediction is made for every tree to obtain a mean predicted value for the population ($\overline{G}p$). The regression model is used to estimate mean increment for the population ($\hat{\overline{G}}_o$) from the difference between the mean predictions for the population and for the growth sample ($\overline{g}_p$):

$$\hat{\overline{G}}_o = \overline{g}_o + b \cdot (\overline{G}_p - \overline{g}_p)$$

The ratio, $\hat{\overline{G}}_o / \overline{G}_p$ is then used as a multiplicative adjustment to the growth model.

As in version 4.0, the model for each species is calibrated independently. In version 5.0, however, there must be five (instead of two) increment observations before the model for a species will be adjusted. The trees on which d.b.h. increment is sampled must be greater than 3 inches d.b.h. at the start of the growth period.

Attenuation of Model Calibration

The model adjustment that is based on input increment data is attenuated over time. For both the large-tree d.b.h. increment model and the small-tree height increment model, the asymptote for attenuation is defined as the average of 1.0 and the original adjustment to the **d.b.h. increment model**. An exponential decay function is then used to approach the asymptote over time; a value midway between the original adjustment and the asymptote will be attained 25 years after the start of the projection.

Assigning Initial Values for Missing Heights

When the height for a tree is missing (as indicated by a blank or zero input value), a height is assigned from a height-diameter function:

$$HT = \exp[C_0 + C_1 \cdot 1/(DBH + 1)] + 4.5$$

The model parameters are given in the User's Guide to the Stand Prognosis Model (Wykoff and others 1982, p. 52).

Version 4.0 used a regression procedure to reestimate C_0 and C_1 when there were four or more height observations for a species. In version 5.0, however, C_1 is held constant and the height sample is used to adjust C_0. Thus the level of the curve shifts but shape is retained. By limiting the calibration to the intercept term, the procedure is less vulnerable to a poor choice of height sample trees. If for instance, the height sample contained only large trees with uniform heights, the estimate for C_1 could be positive, resulting in unrealistically tall height estimates for trees with small d.b.h.'s.

Computing Scribner Board Foot Volume with Variable Merchantability Standards

Volume calculations have been modified in version 5.0 to permit specification of variable top diameter for computing board foot volume. The modification was developed by J. E. Brickell, mensurationist with the USDA Forest Service, Northern Region Timber Management staff, Missoula, MT.

Version 4.0 used equations developed by P. D. Kemp (see Wykoff and others 1982, p. 82), with fixed merchantability standards (9-inch minimum d.b.h., 1-foot stump height, and 8-inch minimum top diameter). An additional set of volume equations (Allen and others 1974) predicts board foot volume assuming a 2-inch minimum d.b.h. and a 2-inch minimum top diameter. These two sets of equations can predict volume to a variable top diameter (D_t) if the tree is considered as four segments (fig. 4). Each segment is assumed to be a tree; d.b.h. of each assumed tree is estimated from the known basal diameter of the segment and height is estimated with a height-diameter function.

The first tree segment (S_1) extends from a 1-foot stump height to a height corresponding to a D_t that is greater than 8 inches. The second segment (S_2) extends from the top of S_1 to the height at which D_t is equal to 8 inches. The third segment (S_3) extends from the top of S_2 to a height at which D_t is less than 8 inches but greater than 2 inches. The final segment (S_4) extends from the top of S_3 to the height at which D_t is equal to 2 inches.

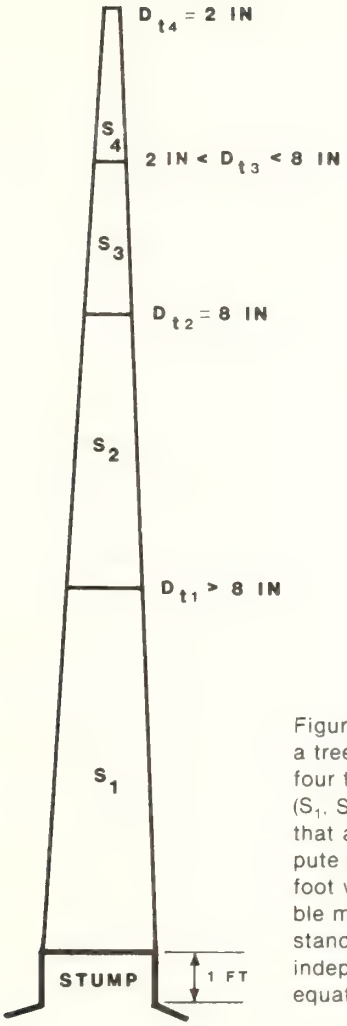


Figure 4.—Diagram of a tree showing the four tree segments (S_1, S_2, S_3, and S_4) that are used to compute Scribner board foot volume to variable merchantability standards using two independent equations.

Table 11.—Map of species onto volume equations for computing Scribner board foot volume from squared d.b.h. and height = (D^2H). Allen's equations are used when D^2H is less than the transition value. Kemp's equations are used when D^2H is greater than the transition value

Species name	Equation used (Allen and others 1974)	Transitional value of D^2H ($in^2 \times ft$)
Western white pine	Lodgepole pine	16,917
Western larch	Western larch	19,232
Douglas-fir	Douglas-fir	15,764
Grand fir	Grand fir	10,017
Western hemlock	Grand fir	14,884
Western redcedar	Western larch	29,922
Lodgepole pine	Lodgepole pine	4,568
Engelmann spruce	Grand fir	6,025
Subalpine fir	Grand fir	19,426
Ponderosa pine	Douglas-fir	14,034
Mountain hemlock	Grand fir	14,884

Allen's and Kemp's equations are both dependent on the product of squared diameter and height (D^2H). For each species, the equations intersect; the point of intersection (T) corresponds to a positive value of D^2H. For D^2H less than T, Allen's equations are used to predict volume to a 2-inch top ($S_1 + S_2 + S_3 + S_4$). If a D_t greater than 2 inches is specified, S_4 is computed with Allen's equation and deducted from the total.

For D^2H greater than or equal to T, Kemp's equation is used to predict volume to an 8-inch top ($S_1 + S_2$). If a D_t greater than 8 inches is specified, Kemp's equation is used again to predict the volume of S_2, which is subtracted from the total. If a D_t of less than 8 inches is specified, ($S_3 + S_4$) and S_4 are estimated with Allen's equation in order to find top volume (S_3), which is added to the total.

Allen's equations were developed only for lodgepole pine, Douglas-fir, western larch, and grand fir. Other species were mapped onto one of these four equations for use in the Prognosis Model. The mapping and the value of D^2H at which Allen's and Kemp's equations give identical results are given in table 11.

Tree Record Compression

Version 5.0 contains a procedure for classifying records into groups that are similar with regard to variables that strongly influence growth predictions. The purpose of this compression algorithm is threefold: (1) to provide space for new records when the regeneration establishment model is called; (2) to eliminate records which, due to thinning or mortality, no longer represent a significant contribution to the stand as a whole; and (3) to reduce the number of tree records so that yield projections are less costly from a computational standpoint, but retain much of the original variation in tree characteristics.

A two-step algorithm is used to compress the tree records (Stage and others in preparation). First, a classification function, which is a weighted linear combination of selected tree attributes (including species, d.b.h., predicted d.b.h. increment, height, crown ratio, and basal area percentile) is used to find the largest gaps in a one-dimensional space. These gaps are used to identify clusters of similar records. In the second step, the larger of the identified clusters (based on the maximum difference in the value of the classification function) are split. Following the second step, the attributes of all of the records in a cluster are averaged to make a single record. Unless the target is changed by the user (see discussion of the COMPRESS keyword) the tree list will be compressed to 150 records.

CHANGES IN FEATURES THAT WERE PART OF VERSION 4.0

Seeding the Random Number Generator

In version 4.0, the random number generator was initialized only at the beginning of the first of several projections in a runstream. As a result, changing the order of projections within a runstream changed the results of the projections. In version 5.0, the random number generator is initialized before each projection so that repeatability of projections is not confounded with their order in the runstream. The sequence of random numbers can be changed by using the RANNSEED record to input a new seed. In version 4.0 there are three seeds; the version 5.0 generator requires only one.

RANNSEED field 1: New seed for random number generator. The seed should be a positive, odd integer value. If otherwise, fractions will be truncated and/or 1 will be added; default = 55329.

Once the RANNSEED record has been used to reseed the random number generator, the input seed will be used to initialize the generator in subsequent projections in the same runstream.

Generating a List of Projected Tree Records

As in version 4.0, a complete list of tree records can be generated for any or all cycles. In addition, the user can now control the dataset reference number for the output file and/or suppress headings. When the no-heading option is selected, a single identification record is printed at the beginning of the list for each cycle. The record contains a flag (the number −999 in columns 1-4), the number of records printed (columns 5-8), and the cycle number (columns 12-13).

TREELIST field 1: The cycle in which a complete list of trees is to be printed. The list is printed at the end of the cycle and the records are updated to include growth for the period. If blank, a list will be generated at the beginning of the projection and at the end of each cycle.

field 2: Dataset reference number for the output tree record file; default = 3.

field 3: Heading suppression indicator. Any numeric entry in this field will prevent headings from being printed; default = print headings.

It is possible to produce more than one tree list in any cycle. For example, if both a printed list and a machine-readable list are desired, a second TREELIST record can be inserted in the runstream to provide a dataset reference number for the machine-readable file:

```
TREELIST          2.0           ␢             ␢
TREELIST          2.0          99.0          999.0
```

In this case, the files will be written at the end of cycle 2 and the second file will be directed to unit 99 with headings suppressed.

Additional Flexibility in Field Sampling Procedures

The interpretation of the DESIGN record has been changed so that it is now possible to sample with two sizes of fixed-area plots where choice of plot size is dependent on tree d.b.h. For example, a 1/20-acre plot could be used to sample large trees with a 1/300-acre plot used to sample seedlings and saplings. A negative value entered in field 1 of the DESIGN record is interpreted as the inverse of the plot area from which large trees were sampled. Thus, the above example could be specified by:

```
DESIGN          -20.0         300.0          5.0           ␢             ␢             ␢
```

where 5 inches is used as the breakpoint (BRK) for determination of plot size.

DESIGN

field 1: Positive value is interpreted as basal area factor for horizontal angle gauge; negative value is interpreted as the inverse of large-tree fixed plot area; default = 40 (square feet/acre/tree).

field 2: Inverse of small-tree fixed plot area; default = 300 ($acre^{-1}$).

field 3: BRK; default = 5 (inches).

field 4: Number of plots in the stand. If blank, or zero, the number of plots in the stand is determined by counting the numbers of unique plot identification codes on the tree records.

field 5: Number of nonstockable plots in the stand. These include plots falling on rock outcroppings, roads, streams, etc. If blank, count nonstockable plots on tree records (IMC = 8; see discussion of tree records in version 4.0 User's Guide [Wykoff and others 1982]).

field 6: Sampling weight for stand. This weight does not affect the projection but is used in programs that aggregate many projections to produce a composite yield table; default = number of plots.

Tree Records Can Be Completely Removed in Thinning

In version 4.0, no more than 99 percent of any tree record could be removed in any one thinning. This constraint has been removed. The CUTEFF record in version 5.0 can specify a cutting efficiency parameter ranging from 0.01 to 1.0. If 1.0 is specified, and a tree is removed, the tree record will be deleted from the list. The maximum of 1.0 also applies to the cutting efficiency parameter entered on a specific thinning request (see next page).

CUTEFF field 1: Proportion of the trees per acre represented by a record that is eliminated if a tree is designated for removal in any thinning. The value of this parameter must fall between 0.01 and 1.0 or the keyword will be ignored; default = 0.98.

D.b.h. Limits Added to Thinning Options

The thinning keywords that are used to specify a stand density target can now be applied within user-selected d.b.h. limits. Only trees with d.b.h.'s between the selected limits will be removed in a thinning. The minimum and maximum d.b.h. values are entered respectively on fields 4 and 5 of the keyword records.

THINBTA — Thin from below to a trees-per-acre target.

THINATA — Thin from above to a trees-per-acre target.

THINBBA — Thin from below to a basal area-per-acre target.

THINABA — Thin from above to a basal area-per-acre target.

field 1: Year in which thinning is requested; if blank, schedule at start of projection.

field 2: The desired residual stand density (trees per acre or basal area per acre, depending on the keyword). If a residual density is not specified, the thinning request will be ignored.

field 3: The cutting efficiency parameter to be used only with this thinning request. If blank, or outside the range 0.01 - 1.0, use the value specified on the CUTEFF record.

field 4: Smallest d.b.h. to be considered for removal; default = 0.0.

field 5: Largest d.b.h. to be considered for removal; default = 999.0.

As an example, a stand is to be thinned from above to a residual density of 100 trees per acre. In addition, no trees that are less than 16 inches d.b.h. are to be removed. This prescription can be simulated by:

```
THINATA        1984.0          100.0          0.5          16.0
```

The d.b.h. limits (16.0 and 999.0 in this example) and the cutting efficiency parameter (0.5 in this example) may constrain the actual removal to less than the specified target. If, in this example, there are 200 trees per acre in 1984, and half of these are greater than 16 inches d.b.h., only 50 trees will actually be removed, leaving a residual stand with 150 trees per acre.

Access to the COVER Extension

In version 5.0, the SHRUB and COVER extensions have been functionally combined, and access to either is provided by inserting the COVER keyword in the runstream for a projection. Keywords associated with COVER are described by Moeur (1985).

COVER field 1: Cycle to begin COVER calculations. Once begun, COVER calculations will be made each cycle until the end of the projection; default = beginning of projection.

field 2: Dataset reference number for COVER output file; default = 18.

In version 4.0, probability of occurrence, cover, and height predictions are made for 16 shrub species on three habitat types (grand fir/*Clintonia*, western redcedar/*Clintonia*, and western hemlock/*Clintonia*). In version 5.0, these equations have been replaced and expanded to represent 31 shrub species on 34 habitat types. The conifer crown width and foliage models are identical in versions 4.0 and 5.0.

Interpreting Stand Information Data

There have been two minor changes in the interpretation of data on the STDINFO record. In version 4.0, when the habitat type code indicates a phase that is not recognized by the model, the habitat code is ignored (model coefficients for type 999 are used). In version 5.0, phase designations are ignored; the code is rounded to habitat type and coefficients for the type are used.

The second change involves assignment of default values when more than one STDINFO record is found in the set of keyword records for a single projection. In version 4.0, the first record is entirely ignored if a second is encountered. Thus, blank fields are assigned the default parameter values indicated in the User's Guide. In version 5.0, blank fields on second and subsequent records are assigned values from data entered on the first record.

The field definitions for the STDINFO record have not changed.

Mortality Multipliers

Parameters have been added to fields 4 and 5 of the MORTMULT record in order to specify a range of d.b.h.'s to which the multipliers will be applied. As in version 4.0, once implemented, the multipliers and diameter limits are in effect for remaining cycles in a projection or until overridden by a subsequent MORTMULT record. Also, only one multiplier and one set of diameter limits can be specified for each species in any cycle.

MORTMULT field 1: Cycle in which mortality multiplier is to be applied. Once multipliers take effect, they remain in effect until replaced with a subsequent request. If blank, multipliers take effect at the start of the projection.

field 2: Species number (see appendix A, table 14) to which multiplier is to be applied; default = all species.

field 3: The value of the multiplier to be used; default = 1.0.

field 4: Minimum d.b.h. to which multiplier will be applied; default = 0.0.

field 5: Maximum d.b.h. to which multiplier will be applied; default = 999.0.

Tree Records

In version 5.0, the interpretation of increment data has changed slightly. With calibration options 1 and 3 (see Wykoff and others 1982, p. 20), increments are input as the difference between two successive d.b.h. or height measurements; the value entered as d.b.h. or height increment is actually a d.b.h. or height—the program automatically performs the subtraction. In version 4.0 with calibration options 1 and 3, input increments of 0 are treated as real measurements and input increments that are exactly equal to the d.b.h. or height measurements are ignored. In version 5.0, only non-zero entries in the increment fields are treated as growth samples regardless of the method used to enter increment data. Further, when increment is computed as the difference between two successive height or d.b.h. measurements, all negative values are rejected.

Point-specific site descriptors have been added to the tree records as an optional input to facilitate the regeneration establishment model. Data that may be entered include slope, aspect, habitat type, topographic position, and site preparation; the coding of these variables is described by Ferguson and Crookston (1984, p. 21). The default tree record format has not changed other than to accommodate the optional point-specific site descriptors.

The optional input is read from the tree records when field 2 of the TREEDATA record is not blank.

TREEDATA field 1: Dataset reference number for tree record input file; default = 2.

field 2: Any numeric value in this field will cause point-specific site descriptors to be read from tree records. Default = point-specific site descriptors are not read.

NEW OPTIONS

Options have been included in version 5.0 that add flexibility to activity schedules, provide better description of the input data, permit variable merchantability standards for computing board foot volume, and afford greater control of growth functions.

Event Monitor

The event monitor schedules management activities conditional on the status of selected stand attributes or the occurrence of certain management activities. The IF record indicates that subsequent records contain information for the event monitor. IF is followed by a logical expression coded on one or more supplemental data records. A THEN record signals the end of the logical expression and is followed by one or more keywords for Prognosis Model activities. An ENDIF record signals the end of event monitor information. For example,

```
IF
(BBA  GT  120)
THEN
THINBBA        b        80
ESTAB
END
ENDIF
```

will result in a thinning from below to 80 ft^2 of basal area followed by a call to the regeneration establishment model each time stand basal area reaches 120 ft^2.

Any activity that can be scheduled normally can be alternatively scheduled with the event monitor; the scheduling date (field 1) on the activity keyword is then interpreted as a delay. If the date entered is 10, the activity will be scheduled 10 years following the first time that the logical expression is true.

Crookston (1985) gives further examples along with complete instructions for coding keywords and logical expressions.

Variable Merchantability Standards for the Board Foot Volume Equations

The BFVOLUME record changes the merchantability standards for the board foot volume equations. The parameters for BFVOLUME are the same as for VOLUME in version 4.0, except that values entered for stump height are ignored. Minimum d.b.h. and minimum top diameter may be changed by cycle for any or all species.

BFVOLUME field 1: Number of the cycle in which new merchantability standards are to take effect; default is beginning of projection.

field 2: Species number (see appendix A, table 14) for the species that is to be affected by the merchantability limits; default is all species.

field 3: Minimum merchantable d.b.h. (inches). Trees with smaller d.b.h. will have no board foot volume. If the number entered here is less than the top diameter (field 4), the value specified for minimum top diameter will be used for minimum d.b.h. as well; default = 6.0 for lodgepole pine, 7.0 for all other species.

field 4: The minimum top diameter (inches); default = 4.5.

Descriptive Statistics for Input Data

An optional output table gives a statistical description of the input data for a projection. This table is requested with the STATS record. Statistics reported include board foot volume, cubic foot volume, trees per acre, and basal area per acre for each species present in the stand. Also given are the mean, standard deviation, coefficient of variation, and confidence limits across sample plots for stand totals of these volume and density measures. Significance level is input in field 1 of the STATS record; the corresponding value of Student's t is computed by the program.

STATS field 1: Significance level for computing confidence limits; default = 0.05.

Starting Projections from Bare Ground

With the Establishment Model in place, it is now possible to begin projections without tree records. To do this, a NOTREES record must be inserted in the runstream. There are no associated parameters. The establishment model (Ferguson and Crookston 1984) can then be used to generate a list of seedlings based on stand parameters and proposed treatment strategies.

Compressing the Tree List

When there are many records in the tree list, the record-compression algorithm can reduce the number of records while minimizing loss of within-stand variation in tree attributes that are important for increment prediction. As a result, the number of calculations required for the projection (and the cost of the projection) can be substantially reduced without significant bias. Compression of the tree list is requested with the COMPRESS record; there are four associated parameters:

COMPRESS field 1: Cycle in which tree list will be compressed; default is the beginning of the projection.

field 2: Number of tree records that will remain following compression; default = 150.0.

field 3: Percentage of new records that will be determined by finding the largest gaps in the classification space. Remainder of records will result from splitting the classes with the greatest variation; default = 50.0.

field 4: Any numeric entry will cause debug output to be printed for the compression algorithm; default is no compression debug output.

If COMPRESS is specified for the first or second cycle, the tree records will be subsequently tripled unless NOTRIPLE or NUMTRIP (see Wykoff and others 1982, p. 93) is used to suppress the record tripling feature.

Simulating Top Mortality

Two options were included in version 5.0 to simulate the effects of defoliation by insects when interactive population dynamics models are unavailable. By using the HTGSTOP record, height growth may be set to zero for randomly selected tree records with heights between user-specified limits. The TOPKILL record provides for permanently removing a randomly selected proportion of the top as well. There are five parameters on the HTGSTOP record to indicate timing, species affected, upper and lower height limits, and the probability that the tree will not grow in height. These same five parameters are entered on the TOPKILL record along with a mean and standard deviation for the distribution describing the proportion of total tree height lost to TOPKILL. This distribution is assumed to be Normal, but in no case will a tree's crown ratio be reduced to less than 5 percent or will the maximum change in total height be greater than 25 percent.

HTGSTOP
TOPKILL

field 1: Cycle in which top-kill and/or growth loss will be simulated; default is first cycle.

field 2: Species that will be affected; default is all species.

field 3: Lower limit of range of heights that will be affected; default = 0.0.

field 4: Upper limit of range of heights that will be affected; default = 0.0.

field 5: Probability that a tree will experience top-kill or growth loss; default = 0.0.

For TOPKILL record only:

field 6: Mean of the distribution of the proportion of total tree height lost to top-kill; default = 0.0.

field 7: Standard deviation of the distribution of the proportion of total tree height lost to top-kill; default = 0.0.

Top damage will only be simulated in the cycle that is specified on the HTGSTOP or TOPKILL record. Periodic infestations can be simulated by including HTGSTOP or TOPKILL records for additional cycles.

CHANGES IN PROGRAM OUTPUT

Although the format of the base model output has not changed greatly in version 5.0, additions to the base model have resulted in new tables. There have also been subtle changes to the output that result from new or expanded options and from changes in the interpretation of input data on the frequency of nonstockable plots.

The regeneration establishment model and the SHRUBS and CANOPY models produce output tables that summarize the operation of these models when they are invoked. These tables are explained in the appropriate User's Manual (Ferguson and Crookston 1984; Moeur 1985). The STATS option produces another new table that displays the distribution of stand attributes by species and by sample plot when more than one plot is used to inventory the stand (fig. 5).

The change in the interpretation of input data on the frequency of nonstockable plots resulted in adjustments to the per-acre values reported for stand attributes. As was earlier described, trees per acre represented by a tree record is now computed on the basis of stockable area. When nonstockable

GENERAL SPECIES SUMMARY FOR THE CRUISE

SPECIES	BOARD FEET	CUBIC FEET	TREES PER ACRE	BA PER ACRE
WESTERN LARCH	904.9	218.9	44.5	16.0
DOUGLAS-FIR	1380.0	419.3	207.0	19.4
GRAND FIR	405.9	339.8	177.9	20.0
WESTERN HEMLOCK	0.0	48.2	17.4	4.0
WESTERN REDCEDAR	0.0	90.4	111.1	9.7
LODGEPOLE PINE	1883.5	506.4	31.8	16.0

DISTRIBUTION OF STAND ATTRIBUTES AMONG SAMPLE POINTS

CHARACTERISTIC	MEAN	STD. DEV.	COEF VAR	SAMPLE	95% CONFIDENCE LIMITS	
TREES PER ACRE	589.65	524.54	0.89	10	214.31	964.99
CUBIC FEET/ACRE	1622.98	922.21	0.57	10	963.09	2282.86
SCRIBNER BF/ACRE	4574.18	3886.39	0.85	10	1793.27	7355.09
BASAL AREA /ACRE	85.13	39.45	0.46	10	56.90	113.36

Figure 5.—Prognosis Model output table produced by the STATS option.

points are present in an inventory, the "STAND COMPOSITION" table (Wykoff and others 1982; fig. 7, pp. 34-35) and the table displaying "ATTRIBUTES OF SELECTED SAMPLE TREES" and "ADDITIONAL STAND ATTRIBUTES" (Wykoff and others 1982; fig. 8, pp. 36-37) now display per-acre stand and tree attributes on the basis of stockable area. The table headings have been modified to reflect the change (figs. 6 and 7). The "SUMMARY STATISTICS" table (Wykoff and others 1982; fig. 9, p. 37) still reports per-acre stand attributes on the basis of total stand area. The table heading, however, has been modified for contrast (fig. 8). The trees per acre reported for each tree record when the TREELIST option is used is still based on total stand area as well.

If nonstockable plots are present in an inventory, the "OPTIONS SELECTED BY DEFAULT" table now reports the ratio of stockable to total plots and the basis for computing per-acre attributes in each of the major tables (fig. 9).

The final change in program output results from the implementation of the regeneration establishment model, the compression algorithm, and the complete removal of tree records in thinning. When tree records are added or deleted, a realignment of the records displayed in the "ATTRIBUTES OF SELECTED SAMPLE TREES" table is necessary. Changes are noted by placing asterisks (**) following the date that records are reselected. An explanatory note is also appended to the table (fig. 7).

CONCLUSIONS

There are substantial changes in program operation and model formulation represented in version 5.0. As a result, the program affords both greater flexibility and improved performance. Permanent sample plots were used to compare version 5.0 with previously available methods of growth projection for Northern Rocky Mountain conifers. Results show that version 5.0 projections of stand attributes have smaller biases and smaller error variances than do projections produced by other methods (Wykoff 1985; Stage in preparation).

STAND GROWTH PROGNOSIS SYSTEM VERSION 5.1 -- INLAND EMPIRE

STAND ID: S248112 MANAGEMENT CODE: NONE SHELTERWOOD PRESCRIPTION FROM THE USER'S MANUAL

STAND COMPOSITION (BASED ON STOCKABLE AREA)

YEAR	STAND ATTRIBUTES	PERCENTILE POINTS IN THE DISTRIBUTION OF STAND ATTRIBUTES BY DBH (DBH IN INCHES) 10	30	50	70	90	100	TOTAL/ACRE OF STAND ATTRIBUTES	DISTRIBUTION OF STAND ATTRIBUTES BY SPECIES AND 3 USER-DEFINED SUBCLASSES
1977	TREES	0.1	0.1	3.2	6.1	8.5	12.7	590. TREES	27.% DF2, 15.% GF2, 15.% GF1, 10.% C2
	VOLUME:								
	TOTAL	5.8	7.9	9.4	10.0	11.5	12.7	1623. CUFT	24.% LP1, 21.% GF1, 20.% DF1, 12.% L1
	MERCH	8.2	9.4	9.6	10.9	11.5	12.7	1118. CUFT	32.% LP1, 24.% DF1, 15.% L1, 10.% LP2
	MERCH	8.0	9.4	9.6	10.9	11.5	12.7	4574. BDFT	31.% LP1, 23.% DF1, 17.% L1, 10.% LP2
	REMOVAL	0.1	0.1	0.1	1.2	3.2	10.4	326. TREES	48.% DF2, 28.% GF2, 18.% C2, 4.% L2
	VOLUME:								
	TOTAL	8.0	9.6	9.6	10.4	10.4	10.4	255. CUFT	47.% LP2, 40.% DF2, 9.% L2, 4.% C2
	MERCH	9.6	9.6	9.6	10.4	10.4	10.4	217. CUFT	51.% LP2, 41.% DF2, 8.% L2, 0.% ---
	MERCH	8.0	9.6	9.6	10.4	10.4	10.4	911. BDFT	50.% LP2, 37.% DF2, 13.% L2, 0.% ---
	RESIDUAL	4.0	5.3	6.2	7.9	9.5	12.7	264. TREES	33.% GF1, 19.% C1, 19.% DF1, 13.% L1
	ACCRETION	5.3	6.2	7.9	9.4	10.9	12.7	91. CUFT/YR	31.% GF1, 25.% DF1, 13.% LP1, 11.% L1
	MORTALITY	6.1	7.9	8.5	9.5	11.5	12.7	13. CUFT/YR	39.% LP1, 25.% L1, 20.% GF1, 13.% DF1
1987	TREES	5.6	6.8	7.9	9.4	11.2	16.2	242. TREES	33.% GF1, 20.% C1, 19.% DF1, 12.% L1
	VOLUME:								
	TOTAL	7.3	8.9	9.9	11.6	13.7	16.2	2145. CUFT	28.% GF1, 24.% DF1, 21.% LP1, 12.% L1
	MERCH	7.7	9.4	10.4	12.0	13.7	16.2	1763. CUFT	26.% GF1, 25.% DF1, 24.% LP1, 13.% L1
	MERCH	7.9	9.4	10.6	12.4	13.9	16.2	7247. BDFT	26.% LP1, 25.% DF1, 24.% GF1, 15.% L1
	ACCRETION	6.6	7.7	9.0	11.0	13.1	16.2	116. CUFT/YR	36.% GF1, 22.% DF1, 12.% C1, 12.% WH1
	MORTALITY	6.8	8.9	9.4	10.6	12.5	16.2	18. CUFT/YR	36.% LP1, 23.% GF1, 21.% L1, 15.% DF1
1997	TREES	7.2	8.4	9.6	11.1	13.4	19.2	222. TREES	33.% GF1, 21.% C1, 19.% DF1, 11.% L1
	VOLUME:								
	TOTAL	8.4	9.9	11.2	13.4	15.5	19.2	3123. CUFT	31.% GF1, 24.% DF1, 16.% LP1, 10.% L1
	MERCH	8.6	10.2	11.5	13.4	15.6	19.2	2826. CUFT	31.% GF1, 23.% DF1, 17.% LP1, 11.% L1
	MERCH	9.2	10.5	11.7	13.5	15.8	19.2	11998. BDFT	30.% GF1, 25.% DF1, 18.% LP1, 11.% L1
	ACCRETION	8.0	9.6	11.1	12.5	15.1	19.2	141. CUFT/YR	41.% GF1, 20.% DF1, 14.% WH1, 13.% C1
	MORTALITY	8.0	9.8	10.8	12.0	14.3	19.2	28. CUFT/YR	30.% LP1, 24.% GF1, 20.% L1, 18.% DF1
2007	TREES	8.2	9.9	11.3	12.5	15.4	21.7	201. TREES	34.% GF1, 23.% C1, 19.% DF1, 10.% L1
	VOLUME:								
	TOTAL	9.6	11.6	12.8	15.0	17.1	21.7	4248. CUFT	35.% GF1, 23.% DF1, 12.% LP1, 11.% C1
	MERCH	9.9	11.7	13.3	15.1	17.2	21.7	3987. CUFT	35.% GF1, 23.% DF1, 12.% LP1, 11.% WH1
	MERCH	10.0	11.8	13.4	15.4	17.4	21.7	17703. BDFT	34.% GF1, 24.% DF1, 12.% LP1, 11.% WH1
	REMOVAL	7.2	10.0	11.2	11.8	13.4	21.6	44. TREES	43.% L1, 32.% LP1, 11.% C1, 10.% DF1
	VOLUME:								
	TOTAL	10.0	11.2	11.8	12.8	14.5	21.6	897. CUFT	55.% LP1, 39.% L1, 3.% DF1, 2.% C1
	MERCH	10.1	11.3	11.8	12.8	14.5	21.6	828. CUFT	57.% LP1, 40.% L1, 2.% C1, 1.% GF1
	MERCH	10.3	11.3	11.8	13.1	14.7	21.6	3673. BDFT	57.% LP1, 40.% L1, 1.% C1, 1.% GF1
	RESIDUAL	8.2	9.7	11.3	13.3	15.7	21.7	157. TREES	42.% GF1, 26.% C1, 22.% DF1, 10.% WH1
	ACCRETION	9.4	11.3	12.6	14.5	17.0	21.7	144. CUFT/YR	42.% GF1, 20.% WH1, 19.% C1, 18.% DF1
	MORTALITY	9.0	11.3	12.7	15.1	17.2	21.7	19. CUFT/YR	46.% GF1, 34.% DF1, 9.% C1, 9.% WH1
2017	TREES	9.6	11.4	13.1	15.1	17.8	23.3	147. TREES	42.% GF1, 26.% C1, 21.% DF1, 10.% WH1
	VOLUME:								
	TOTAL	11.1	13.1	15.7	17.3	19.2	23.3	4606. CUFT	43.% GF1, 25.% DF1, 16.% WH1, 16.% C1
	MERCH	11.1	13.3	15.9	17.3	19.2	23.3	4397. CUFT	43.% GF1, 25.% DF1, 16.% WH1, 15.% C1
	MERCH	11.4	13.7	16.3	17.6	20.0	23.3	20929. BDFT	43.% GF1, 26.% DF1, 17.% WH1, 13.% C1
	ACCRETION	10.8	12.9	14.8	16.5	19.2	23.3	169. CUFT/YR	44.% GF1, 23.% WH1, 17.% C1, 15.% DF1
	MORTALITY	9.9	12.8	14.4	16.5	18.7	23.3	32. CUFT/YR	50.% GF1, 30.% DF1, 9.% WH1, 9.% C1

Figure 6.—Stand composition table from the Prognosis Model output. This table was produced by the same set of keyword and tree records that were used for an example by Wykoff and others (1982; fig. 7, pp. 34-35). Note the change in table heading that reflects the change in treatment of stockability data. Note also that a nonstockable plot in the inventory resulted in a change in initial conditions.

Figure 6.— (con.)

2027	TREES	10.6	12.8	15.1	17.2	20.6	27.0	136.	TREES	41.% GF1,	27.% C1,	21.% DF1, 11.% WH1
	VOLUME:											
	TOTAL	12.6	15.1	17.2	19.1	21.6	27.0	5972.	CUFT	43.% GF1,	22.% DF1,	18.% WH1, 16.% C1
	MERCH	12.6	15.1	17.2	19.1	21.6	27.0	5746.	CUFT	43.% GF1,	22.% DF1,	18.% WH1, 16.% C1
	MERCH	12.9	15.4	17.4	19.8	21.7	27.0	28917.	BDFT	44.% GF1,	22.% DF1,	21.% WH1, 13.% C1
	ACCRETION	12.6	14.8	15.9	19.1	21.7	27.0	166.	CUFT/YR	51.% GF1,	21.% WH1,	15.% C1, 13.% DF1
	MORTALITY	11.9	14.3	15.9	18.2	20.9	27.0	42.	CUFT/YR	49.% GF1,	29.% DF1,	11.% WH1, 11.% C1
2037	TREES	11.4	14.8	16.4	18.2	22.3	29.5	126.	TREES	41.% GF1,	28.% C1,	20.% DF1, 11.% WH1
	VOLUME:											
	TOTAL	14.3	16.4	18.2	21.4	23.9	29.5	7211.	CUFT	45.% GF1,	20.% DF1,	19.% WH1, 16.% C1
	MERCH	14.3	16.4	18.2	21.4	23.9	29.5	6975.	CUFT	45.% GF1,	20.% DF1,	19.% WH1, 16.% C1
	MERCH	14.8	16.6	18.7	21.8	24.6	29.5	36029.	BDFT	46.% GF1,	22.% WH1,	20.% DF1, 13.% C1
	REMOVAL	12.1	15.1	16.3	17.1	22.3	29.5	91.	TREES	47.% GF1,	38.% C1,	15.% WH1, 0.% L1
	VOLUME:											
	TOTAL	14.3	16.3	16.9	22.1	22.7	29.5	4823.	CUFT	48.% GF1,	28.% WH1,	24.% C1, 0.% LP1
	MERCH	14.3	16.3	16.9	22.1	24.6	29.5	4652.	CUFT	48.% GF1,	28.% WH1,	24.% C1, 0.% LP1
	MERCH	14.8	16.3	17.1	22.1	24.6	29.5	23823.	BDFT	49.% GF1,	32.% WH1,	19.% C1, 0.% LP1
	RESIDUAL	10.9	12.2	18.7	19.7	22.3	29.5	35.	TREES	72.% DF1,	26.% GF1,	2.% C1, 1.% WH1
	ACCRETION	12.2	18.7	19.3	20.7	22.7	29.5	59.	CUFT/YR	54.% GF1,	43.% DF1,	1.% C1, 1.% WH1
	MORTALITY	10.9	17.6	18.9	19.8	22.3	29.5	15.	CUFT/YR	76.% DF1,	24.% GF1,	0.% WH1, 0.% C1
2047	TREES	12.2	13.7	20.4	21.8	24.0	30.6	32.	TREES	70.% DF1,	27.% GF1,	2.% C1, 1.% WH1
	VOLUME:											
	TOTAL	13.7	20.5	21.8	23.3	24.9	30.6	2829.	CUFT	55.% DF1,	43.% GF1,	1.% WH1, 1.% C1
	MERCH	13.7	20.5	21.8	23.3	24.9	30.6	2760.	CUFT	55.% DF1,	43.% GF1,	1.% WH1, 1.% C1
	MERCH	17.9	20.5	21.8	23.3	24.9	30.6	14633.	BDFT	54.% DF1,	44.% GF1,	1.% WH1, 1.% C1
	ACCRETION	12.9	20.3	21.1	23.3	24.9	30.6	57.	CUFT/YR	50.% DF1,	47.% GF1,	2.% WH1, 2.% C1
	MORTALITY	12.9	19.6	20.5	21.8	24.4	30.6	15.	CUFT/YR	80.% DF1,	19.% GF1,	1.% WH1, 0.% C1
2057	TREES	13.4	15.3	21.6	23.2	25.3	31.4	30.	TREES	69.% DF1,	28.% GF1,	2.% C1, 1.% WH1
	VOLUME:											
	TOTAL	15.3	21.7	23.2	24.9	26.7	31.4	3251.	CUFT	53.% DF1,	45.% GF1,	1.% WH1, 1.% C1
	MERCH	15.3	22.0	23.2	24.9	26.7	31.4	3178.	CUFT	53.% DF1,	45.% GF1,	1.% WH1, 1.% C1
	MERCH	18.6	22.3	23.2	24.9	26.7	31.4	17035.	BDFT	53.% DF1,	45.% GF1,	2.% WH1, 1.% C1

STAND GROWTH PROGNOSIS SYSTEM VERSION 5.1 -- INLAND EMPIRE

STAND ID; S248112 MANAGEMENT CODE: NONE SHELTERWOOD PRESCRIPTION FROM THE USER'S MANUAL

	ATTRIBUTES OF SELECTED SAMPLE TREES								ADDITIONAL STAND ATTRIBUTES (BASED ON STOCKABLE AREA)					
YEAR	INITIAL TREES/A %TILE	SPECIES	DBH (INCHES)	HEIGHT (FEET)	LIVE CROWN RATIO	PAST DBH GROWTH (INCHES)	BASAL AREA %TILE	TREES PER ACRE	STAND AGE	QUADRATIC MEAN DBH (INCHES)	TREES PER ACRE	BASAL AREA (SQFT/A)	TOP HEIGHT LARGEST 40/A (FT)	CROWN COMP FACTOR
1977						(10 YRS)								
	10	GF2	0.10	3.00	65	0.00	0.0	90.00						
	30	DF2	0.10	2.00	55	0.00	0.0	90.00						
	50	C2	3.20	17.00	45	0.60	3.0	30.00						
	70	GF1	6.10	38.00	75	1.20	24.8	19.71						
	90	LP1	8.50	59.34	25	0.95	62.4	10.15						
	100	DF1	12.70	67.00	35	1.60	100.0	4.55						
									57	5.1	590.	85.	63.4	104.8
									RESIDUAL:	7.0	264.	71.	64.3	88.0
1987						(10 YRS)								
	10	GF2	1.03	7.54	65	0.85	0.0	0.05						
	30	DF2	0.80	6.18	55	0.61	0.0	0.05						
	50	C2	4.50	23.00	45	1.23	0.0	0.03						
	70	GF1	7.60	47.40	74	1.37	24.9	18.03						
	90	LP1	9.38	66.19	23	0.85	53.8	8.61						
	100	DF1	14.36	76.20	33	1.44	98.4	4.39						
									67	8.6	242.	98.	68.4	117.1
1997						(10 YRS)								
	10	GF2	1.53	10.82	65	0.46	0.0	0.04						
	30	DF2	1.07	8.26	55	0.23	0.0	0.04						
	50	C2	5.68	28.41	55	1.12	0.3	0.03						
	70	GF1	9.19	56.77	72	1.45	23.4	16.75						
	90	LP1	10.15	72.54	19	0.74	40.2	7.08						
	100	DF1	15.84	84.43	30	1.28	96.0	4.18						
									77	10.2	222.	127.	75.6	145.5
2007						(10 YRS)								
	10	GF2	2.04	14.75	65	0.46	0.0	0.03						
	30	DF2	1.52	11.96	55	0.39	0.0	0.02						
	50	C2	7.26	34.05	58	1.50	1.1	0.03						
	70	GF1	11.71	68.37	72	2.31	39.5	15.58						
	90	LP1	11.24	79.52	16	1.06	30.4	5.60						
	100	DF1	17.03	91.58	28	1.03	89.3	3.93						
									87	11.9	201.	154.	78.0	168.4
									RESIDUAL:	12.1	157.	126.	77.0	141.3
2017 **						(10 YRS)								
	10	C1	9.62	45.71	23	1.33	4.6	8.78						
	30	GF1	10.78	74.01	38	0.98	11.6	1.12						
	50	GF1	13.08	70.48	60	1.62	32.4	1.05						
	70	C1	16.10	60.49	68	2.67	57.8	0.72						
	90	GF1	17.59	104.94	59	1.73	76.3	1.72						
	100	DF1	22.53	102.62	30	0.74	98.1	0.25						
									97	13.9	147.	155.	84.3	168.2
2027						(10 YRS)								
	10	C1	9.96	49.92	20	0.32	2.5	8.36						
	30	GF1	12.41	84.32	37	1.49	13.1	0.99						
	50	GF1	13.82	78.18	56	0.67	20.8	0.98						
	70	C1	16.73	65.51	67	0.60	51.2	0.69						
	90	GF1	18.21	111.24	56	0.57	65.1	1.63						
	100	DF1	24.12	108.95	29	1.38	97.9	0.23						
									107	15.6	136.	182.	89.8	189.2
2037						(10 YRS)								
	10	C1	10.53	55.03	19	0.55	2.3	7.69						
	30	GF1	14.48	95.10	36	1.90	14.6	0.92						
	50	GF1	15.07	87.27	54	1.14	16.8	0.84						
	70	C1	17.58	71.00	66	0.80	50.0	0.65						
	90	GF1	19.34	118.69	55	1.03	63.5	1.41						
	100	DF1	24.88	113.61	28	0.66	95.7	0.22						
									117	17.1	126.	200.	96.5	204.7
									RESIDUAL:	17.6	35.	59.	99.6	55.7

(con.)

Figure 7.—Tree and stand attributes table from the Prognosis Model output. As for figure 6, input conditions match those used to produce tables in the example by Wykoff and others (1982; fig. 8, pp. 36-37). Note that the heading has changed to show that per-acre values are based on stockable area and that initial conditions are somewhat different. Note also that when the regeneration establishment model, the compression algorithm, and/or thinning result in the addition or removal of tree records, new tree records are selected for display. The year is flagged with two asterisks (see the year 2047) and an explanatory note is appended to the table.

Figure 7.— (con.)

```
2047 **                                    ( 10 YRS)

        10     DF1      12.24    91.13    22    1.14     5.2    1.78
        30     DF1      12.89    91.82    18    0.57    11.8    4.76
        50     GF1      20.53   111.80    81    1.66    46.9    2.04
        70     DF1      20.50   117.44    34    0.69    39.7    2.05
        90     GF1      24.95   105.95    76    2.45    92.5    1.11
       100     WH1      30.61   101.65    76    1.03   100.0    0.02
                                                          127    19.3      32.      65.    107.5    59.5

2057                                       ( 10 YRS)

        10     DF1      13.39    98.85    21    1.00     5.1    1.65
        30     DF1      13.92    99.07    17    0.89    11.2    4.11
        50     GF1      22.41   120.58    81    1.72    44.3    1.97
        70     DF1      21.51   122.65    32    0.88    30.3    1.87
        90     GF1      26.74   114.71    76    1.64    94.0    1.10
       100     WH1      31.45   107.06    75    0.78   100.0    0.02
                                                          137    20.9      30.      71.    114.6    62.9

** NOTE:  DUE TO HARVEST, COMPRESSION, OR REGENERATION ESTABLISHMENT, NEW SAMPLE TREES WERE SELECTED.
```

STAND GROWTH PROGNOSIS SYSTEM VERSION 5.1 -- INLAND EMPIRE

SUMMARY STATISTICS (BASED ON TOTAL STAND AREA)

		VOLUME PER ACRE				REMOVALS PER ACRE							GROWTH				IDENTIFIERS	
YEAR	AGE	TREES /ACRE	TOTAL CU FT	MERCH CU FT	MERCH BD FT	TREES /ACRE	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA/ ACRE SQFT	CCF	TOP HT FT	PRD YRS	ACC CUFT	MOR/YR	STAND SAMPLE WEIGHT	STAND	MGMT
1977	57	536	1475	1016	4158	296	232	198	828	64	80	64	10	82	12	11	S248112	NONE
1987	67	220	1950	1603	6589	0	0	0	0	89	106	68	10	105	16	11	S248112	NONE
1997	77	202	2839	2569	10908	0	0	0	0	115	132	76	10	128	26	11	S248112	NONE
2007	87	183	3862	3624	16094	40	816	753	3339	114	128	77	10	131	17	11	S248112	NONE
2017	97	134	4187	3997	19027	0	0	0	0	141	153	84	10	153	29	11	S248112	NONE
2027	107	124	5429	5224	26289	0	0	0	0	165	172	90	10	151	39	11	S248112	NONE
2037	117	114	6556	6341	32754	83	4385	4229	21658	54	51	100	10	54	14	11	S248112	NONE
2047	127	29	2572	2509	13302	0	0	0	0	59	54	107	10	52	13	11	S248112	NONE
2057	137	27	2955	2889	15486	0	0	0	0	64	57	115	0	0	0	11	S248112	NONE

Figure 8.—Summary statistics table from the Prognosis Model output. Input conditions are the same as displayed in Wykoff and others (1982; fig. 9; p. 37). The table heading was modified to state that statistics are based on total stand area.

OPTIONS SELECTED BY DEFAULT

```
TREEFMT     (23X,I4,3X, F2.0,I1, A3,F3.1,F2.1,3X,F3.0,T63,F3.0    ,T60,F3.1,T48,  I1,3X, I2,
            2I1,T66,2I1,I3, 2I1)

DESIGN      BASAL AREA FACTOR= 40.0; INVERSE OF FIXED PLOT AREA=  300.0; BREAK DBH      5.0
            NUMBER OF PLOTS=    11; NON-STOCKABLE PLOTS=     1; STAND SAMPLING WEIGHT   11.00000
            STAND ATTRIBUTES ARE CALCULATED PER ACRE OF STOCKABLE AREA.  STAND STATISTICS
            IN SUMMARY TABLE ARE MULTIPLIED BY 0.909 TO INCLUDE TOTAL STAND AREA.
```

Figure 9.—Prognosis Model output table showing options selected by default. This figure illustrates the message produced when nonstockable plots are encountered in the inventory. Contrast to Wykoff and others (1982; fig. 6, pp. 32-33).

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APPENDIX A: SUMMARY OF CODES USED IN THE PROGNOSIS MODEL

Table 12.—Codes for the Forests represented in the Inland Empire version of the Prognosis Model

Forest	Code	Forest	Code
Bitterroot	3	Kaniksu	13
Idaho Panhandle[1]	4	Kootenai	14
Clearwater	5	Lolo	16
Coeur d'Alene	6	Nezperce	17
Colville	7	St. Joe	18
Flathead	10		

[1]The Idaho Panhandle National Forests is an administrative unit that encompasses the Coeur d'Alene, Kaniksu, and St. Joe National Forests. All of the growth models use coefficients for the St. Joe National Forest when the Panhandle is specified.

Table 13.—Codes for habitat types represented in the Inland Empire version of the Prognosis Mode1[1]

Code	Abbreviation	Habitat type name
130	PIPO/AGSP	*Pinus ponderosa/Agropyron spicatum*
170	PIPO/SYAL	*Pinus ponderosa/Symphoricarpos albus*
250	PSME/VACA	*Pseudotsuga menziesii/Vaccinium caespitosum*
260	PSME/PHMA	*Pseudotsuga menziesii/Physocarpus malvaceus*
280	PSME/VAGL	*Pseudotsuga menziesii/Vaccinium globulare*
290	PSME/LIBO	*Pseudotsuga menziesii/Linnaea borealis*
310	PSME/SYAL	*Pseudotsuga menziesii/Symphoricarpos albus*
320	PSME/CARU	*Pseudotsuga menziesii/Calamagrostis rubescens*
330	PSME/CAGE	*Pseudotsuga menziesii/Carex geyeri*
420	PICEA/CLUN	*Picea/Clintonia uniflora*
470	PICEA/LIBO	*Picea/Linnaea borealis*
510	ABGR/XETE	*Abies grandis/Xerophyllum tenax*
520	ABGR/CLUN	*Abies grandis/Clintonia uniflora*
530	THPL/CLUN	*Thuja plicata/Clintonia uniflora*
540	THPL/ATFI	*Thuja plicata/Athyrium filix-femina*
550	THPL/OPHO	*Thuja plicata/Oplopanax horridum*
570	TSHE/CLUN	*Tsuga heterophylla/Clintonia uniflora*
610	ABLA/OPHO	*Abies lasiocarpa/Oplopanax horridum*
620	ABLA/CLUN	*Abies lasiocarpa/Clintonia uniflora*
640	ABLA/VACA	*Abies lasiocarpa/Vaccinium caespitosum*
660	ABLA/LIBO	*Abies lasiocarpa/Linnaea borealis*
670	ABLA/MEFE	*Abies lasiocarpa/Menziesia ferruginea*
680	TSME/MEFE	*Tsuga mertensiana/Menziesia ferruginea*
690	ABLA/XETE	*Abies lasiocarpa/Xerophyllum tenax*
710	TSME/XETE	*Tsuga mertensiana/Xerophyllum tenax*
720	ABLA/VAGL	*Abies lasiocarpa/Vaccinium globulare*
730	ABLA/VASC	*Abies lasiocarpa/Vaccinium scoparium*
830	ABLA/LUHI	*Abies lasiocarpa/Luzula hitchcockii*
850	PIAL-ABLA	*Pinus albicaulis/Abies lasiocarpa*
999	OTHER	

[1]From Pfister and others (1977).

Table 14.—Tree species recognized by the Prognosis Model with default coding conventions

Common name	Scientific name	Default input code	Numeric code
Western white pine	*Pinus monticola*	WP	1
Western larch	*Larix occidentalis*	L	2
Douglas-fir	*Pseudotsuga menziesii*	DF	3
Grand fir	*Abies grandis*	GF	4
Western hemlock	*Tsuga heterophylla*	WH	5
Western redcedar	*Thuja plicata*	C	6
Lodgepole pine	*Pinus contorta*	LP	7
Engelmann spruce	*Picea engelmannii*	S	8
Subalpine fir	*Abies lasiocarpa*	AF	9
Ponderosa pine	*Pinus ponderosa*	PP	10
Mountain hemlock	*Tsuga mertensiana*		11

Table 15.—Aspect codes

Aspect	Azimuth (degrees)	Code
North	337.5 - 22.5	1
Northeast	22.6 - 67.5	2
East	67.6 - 112.5	3
Southeast	112.6 - 157.5	4
South	157.6 - 202.5	5
Southwest	202.6 - 247.5	6
West	247.6 - 292.5	7
Northwest	292.6 - 337.5	8
Level		9

Table 16.—Slope codes

Slope angle (%)	Code
≤ - 5	0
6 - 15	1
16 - 25	2
26 - 35	3
36 - 45	4
46 - 55	5
56 - 65	6
66 - 75	7
76 - 85	8
≥ 86	9

Table 17.—Crown ratio codes

Crown ratio (%)	Code
1 - 10	1
11 - 20	2
21 - 30	3
31 - 40	4
41 - 50	5
51 - 60	6
61 - 70	7
71 - 80	8
≥ 81	9

Table 18.—Interpreting damage codes **(IDCD)**

Code	Interpretation
73	Tree top is missing
74	Tree top is dead
all others	Ignored

Table 19.—Interpreting tree history codes **(ITH)**

Code	Interpretation
5	Tree died during mortality observation period; record is used to backdate density for model scaling, but is not projected.
6,7	Tree died prior to mortality observation period; record is ignored.
9	Special record (planar intercept in Northern Region inventory); record is ignored.
1,2,3,4,8	Various categories of live trees; records are projected.

Table 20.—Interpreting tree value codes (IMC)

Code	Interpretation
1	Desirable tree
2	Acceptable tree
3	Live cull
8	Nonstockable point

All other codes are interpreted as 3

APPENDIX B: SUMMARY OF KEYWORDS, ASSOCIATED PARAMETERS, AND DEFAULT CONDITIONS

Note: Appendix B contains summaries of keywords that are presented in both the version 5.0 supplement and the original User's Guide (Wykoff and others 1982). For a more detailed description, refer to the page number given beneath each keyword. Numbers preceded by the letter "S" are for either new or updated options and the indicated pages are found in this supplement. Otherwise, refer to the User's Guide.

Rules for Coding Keyword Records

1. All option keywords start in column 1.

2. The numerical values (parameters) needed to implement an option are contained in seven numeric fields that are 10 columns wide. The first parameter field begins in column 11. Values should either be right-justified in the numeric field or be followed by a decimal point.

3. Blank numeric fields are not treated as zeroes. If a blank field is found, the default value will be used. If zeroes are to be specified, they must be punched. Thus, only the numeric values that are different from the default parameter values need to be specified.

4. All supplemental data records associated with a keyword must be provided if the keyword is used.

5. When two or more conflicting options are specified, the last one specified will be used.

Controlling Program Execution

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
INVYEAR (8)	Specify the starting date for a projection. field 1: Year in which simulation is to begin.	0
NUMCYCLE (8)	Specify the number of cycles in a projection. field 1: Number of cycles to be projected; maximum number of cycles is 40.	1
PROCESS (8)	Marks the end of an input file for a single projection in a runstream and triggers the beginning of the simulation. Must be present or projection will not run.	
STOP (8)	Signal the end of Prognosis Model runstream.	
TIMEINT (8)	Specify the length of any or all projection cycles. field 1: Number of a cycle whose length is to be changed. field 2: Number of years to be simulated in the cycle(s) referenced in field 1.	Change all cycles 10 years

Entering Stand and Tree Characteristics

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
DESIGN (10, S-15)	Enter inventory design parameters.	
	field 1: If positive, basal area factor for variable radius plots; if negative, inverse of fixed area plot for sampling large trees.	40 ft^2/acre/tree
	field 2: Inverse of fixed plot area for measuring small trees.	300 plots/acre
	field 3: d.b.h. separating large from small trees.	5 inches
	field 4: Number of plots used to inventory stand.	Count the plots
	field 5: Number of nonstockable plots in stand inventory.	Count the plots
	field 6: Stand weight for aggregation of projections.	Number of plots
GROWTH (20)	Identify methods used to measure and input mortality and height and diameter increment data.	
	field 1: Method used to measure diameter increment.	0 (past increment)
	field 2: Length of diameter increment measurement period.	10 years
	field 3: Method used to measure height increment.	0 (past increment)
	field 4: Length of height increment measurement period.	5 years
	field 5: Length of mortality observation period.	5 years
MGMTID (11)	Enter an alphanumeric code to identify the silvicultural treatment simulated in a projection. The code does not affect the projection but is printed with each output table and on each line in the summary table.	Default code is "NONE" (MGMTID record not input); if supplemental record is blank, management identifiers not printed
	Supplemental record: enter management identifier in first four columns.	
SPCODES (19)	Identify species codes used on the input tree records.	
	field 1: Numeric code for the species for which the code is to be changed.	Change for all species.
	Supplemental record: Species code or codes, left justified in consecutive 4-column fields. If all codes are replaced, they must be entered in order of numeric code. If only one code is replaced, it is entered in the first 4 columns.	Default values are given in table 14; a blank entry on the supplemental record will be interpreted as a blank
STDIDENT (11)	Enter stand identification code and descriptive title to label the output.	
	Supplemental record: Stand identification code is entered in columns 1-8; title is entered in columns 9-80.	
STDINFO (12,S-17)	Enter data that describe the site on which stand is located.	
	field 1: National Forest on which stand is located.	18 (St. Joe)
	field 2: Stand habitat type code.	260 (PSME/PHMA)
	field 3: Stand age.	0 years
	field 4: Stand aspect code.	9 (level)
	field 5: Stand slope code.	0 (<5%)
	field 6: Stand elevation code.	38 hundred feet
	field 7: Stand site index.	0
TREEDATA (18, S-17)	Read tree data from dataset referenced by the unit number recorded in field 1.	
	field 1: Dataset reference number.	2
	field 2: Indicate that point-specific site descriptors are included with tree records.	No point-specific site descriptors on tree records

(con.)

Entering Stand and Tree Characteristics (Con.)

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
TREEFMT (19)	Provide a format statement that describes the layout of a tree record. Two supplemental records: A FORTRAN execution time format statement.	See table 5, Wykoff and others 1982

Modifying Tree Volume Calculations

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
BFFDLN MCFDLN (24)	Enter species-specific parameters for log-linear form and defect correction equation for board foot volume estimates (BFFDLN) or merchantable cubic foot volume estimates (MCFDLN). field 1: Numeric code for the species for which the equation is to be changed. The default equation supplies a multiplier of 1.0 for each species. field 2: Intercept term for log-linear equation. field 3: Slope coefficient for log-linear equation.	 Change all species 0.0 1.0
BFFDPOLY MCFDPOLY (23)	Enter species-specific parameters for polynomial form and defect correction equation for board foot volume estimates (BFFDPOLY) or merchantable cubic foot volume estimates (MCFDPOLY). field 1: Numeric code for the species for which the equation is to be changed. The default equation supplies a multiplier of 1.0 for all species. field 2: Intercept term for polynomial equation. field 3: Coefficient for linear term in polynomial equation. field 4: Coefficient for quadratic term in polynomial equation. field 5: Coefficient for cubic term in polynomial equation. field 6: Coefficient for quartic term in polynomial equation.	 Change all species 1.0 0.0 0.0 0.0 0.0
BFVOLUME VOLUME (22, S-18)	Redefine the merchantability limits for the merchantable cubic foot volume equation. field 1: Cycle in which limits defined below will be implemented. field 2: Numeric code for the species for which limits are to be changed. field 3: Minimum d.b.h. field 4: Minimum top diameter. field 5: Stump height.	 Implement at start of projection Change for all species 6 inches for lodgepole pine 7 inches for all other species 4.5 inches 1 foot
MCFDLN	Parameters same as for BFFDLN.	
MCFDPOLY	Parameters same as for BFFDPOLY.	
VOLUME	Parameters same as for BFVOLUME.	

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
CUTEFF (21, S-15)	Change the assumed effectiveness of thinning for all thinning activities.	
	field 1: New value for global cutting efficiency parameter.	0.98
MINHARV (22)	Specify minimum acceptable harvest standards for board foot volume, merchantable cubic foot volume, or basal area per acre by cycle.	
	field 1: The cycle in which minimum harvest standards will be applied.	Applied in all cycles
	field 2: The minimum acceptable harvest volume in merchantable cubic feet per acre.	0 ft^3/acre
	field 3: The minimum acceptable harvest volume in board feet per acre.	0 bd ft/acre
	field 4: The minimum acceptable harvest in square feet of basal area per acre.	0 ft^2/acre
SPECPREF (26)	Change the species component of the removal priority formula.	
	field 1: Date at which change is to be implemented.	Implement at start of projection
	field 2: Numeric code for species whose removal priority is to be changed.	Ignore the SPECPREF request
	field 3: Species preference value.	0
TCONDMLT (27)	Change the impact of tree value class on the determination of removal priority.	
	field 1: Date at which change is to be implemented.	Implement at start of projection
	field 2: New tree condition class multiplier.	100
THINABA THINATA (27, S-16)	Schedule thinning from above to a basal area per acre (THINABA) or a trees per acre (THINATA) target.	
	field 1: Date that thinning is scheduled.	Schedule at start of projection
	field 2: The residual stand density.	Ignore the thinning request
	field 3: Cutting efficiency parameter specific to this thinning request.	0.98
	field 4: d.b.h. of smallest tree that will be cut.	0 inches
	field 5: d.b.h. of largest tree that will be cut.	999 inches
THINAUTO (28)	Schedule automatic stocking control. As nearly as is possible, stand density will be maintained within a range determined by the minimum and maximum percentage of normal stocking entered in fields 2 and 3.	
	field 1: Date that automatic stocking control is scheduled to begin.	Begin at start of projection
	field 2: Percentage of normal stocking that defines the lower limit for stand density.	45%
	field 3: Percentage of normal stocking that defines the upper limit for stand density.	60%
	field 4: Cutting efficiency parameter specific to automatic stocking control request.	0.98

(con.)

Specifying Management Activities (Con.)

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
THINBBA THINBTA (27, S-16)	Schedule thinning from below to a basal area per acre (THINBBA) or trees per acre (THINBTA) target. field 1: Date that thinning is scheduled. field 2: The residual stand density. field 3: Cutting efficiency parameter specific to this thinning request. field 4: d.b.h. of smallest tree that will be cut. field 5: d.b.h. of largest tree that will be cut.	 Scheduled at start of projection Ignore the thinning request 0.98 0 inches 999 inches
THINDBH (24)	Schedule the removal of a segment of the d.b.h. distribution. field 1: Date that thinning is scheduled. field 2: Smallest d.b.h. to be removed. field 3: Largest d.b.h. to be removed. field 4: Cutting efficiency parameter specific to this request.	 Scheduled at start of projection 0 inches 999 inches 0.98
THINPRSC (24)	Schedule prescription thinning. Harvest trees that were marked for removal on the input tree records. field 1: Date that prescription thinning is scheduled. field 2: Cutting efficiency parameter specific to this thinning request.	 Scheduled at start of projection 0.98

Controlling Program Output

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
COMMENT (48)	Enter a comment that will be reproduced in the Input Summary Table. Supplemental records: Enter your comment using all 80 columns on as many records as desired. Signify the end of your comment by supplying a record with the word "END" entered in the first 3 columns. The 4th column must be blank.	 None
ECHOSUM (48)	Request that summary output be copied to a retrievable data storage file. field 1: Dataset reference number for output file.	 4
TREELIST (47, S-14)	Print a list of all sample tree records. field 1: Cycle in which tree list is to be printed. field 2: Dataset reference number. field 3: If any number is entered in field 3, tree list will be printed without headings.	 Print tree list in all cycles 3 Print headings

Linkage to Prognosis Model Extensions

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
CHEAPO (86)	Generate output file required for subsequent execution of the CHEAPO economic analysis program.	
	field 1: Dataset reference number for CHEAPO output file.	11
COVER (86, S-16)	Indicates the start of special keyword input file for the CANOPY and/or SHRUBS extensions.	
	field 1: Cycle to begin COVER calculations.	Beginning of projection
	field 2: Dataset reference number for COVER output.	18
DFTM (85)	Indicates start of special keyword input file for the Douglas-fir tussock moth extension.	
END (85)	Indicates end of special keyword input file for any extension.	
ESTAB (86)	Indicates start of special keyword input file for the regeneration establishment extension.	
MPB (85)	Indicates start of special keyword input file for the mountain pine beetle extension.	
WSBW (85)	Indicates start of special keyword input file for the western spruce budworm extension.	

Growth Prediction Modifiers and Special Input/Output Options

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
ADDFILE (95)	Specify a dataset reference number for a supplemental keyword record file.	
	field 1: Dataset reference number.	None
BAIMULT HTGMULT REGDMULT REGHMULT (94)	Enter multiplier to change prediction of tree basal area increment (BAIMULT), large tree height increment (HTGMULT), small tree diameter increment (REGDMULT), or small tree height increment (REGHMULT).	
	field 1: Cycle in which growth multiplier takes effect.	Apply in all cycles
	field 2: Numeric code for species to which growth multiplier is to be applied.	Apply to all species
	field 3: Growth multiplier.	1.0
BAMAX (95)	Modify the maximum basal area used to control mortality predictions.	
	field 1: Maximum basal area.	See table 17, Wykoff and others (1982)
COMPRESS (S-19)	Reduce the number of tree records used to represent the stand.	
	field 1: Cycle in which tree list will be compressed.	Beginning of projection
	field 2: Number of tree records that will remain after compression.	150
	field 3: Percentage of new records that will be determined by finding the largest gaps in the classification space; remainder will be determined by splitting the classes with the most variation.	50
	field 4: Numeric entry prints debug. Output from compression algorithm.	No Debug output

(con.)

Growth Prediction Modifiers and Special Input/Output Options (Con.)

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
DATELIST (96)	Instruct program to print date of last revision for Prognosis Model subprograms and common areas.	None
DEBUG (96)	Request printout of the results of most program calculations in any or all cycles.	
	field 1: Cycle in which debug output is to be printed.	Print in all cycles
DGSTDEV (93)	Change the limits of the Normal distribution from which random errors are drawn for increment predictions.	
	field 1: Number of standard deviations that define the bounds of distribution.	2.0
HTGMULT	Parameters same as for BAIMULT.	
HTGSTOP TOPKILL (S-20)	Set height increment to zero or kill top for a random sample of trees.	
	field 1: Cycle in which top-kill or growth loss will be simulated.	First cycle
	field 2: Species that will be affected.	All species
	field 3: Lower limit of range of heights that will be affected.	0.0
	field 4: Upper limit of range of heights that will be affected.	0.0
	field 5: Probability that a given tree will receive top-kill or growth loss.	0.0
	field 6: Mean of the distribution of the proportional total tree height lost to top-kill (TOPKILL record only).	0.0
	field 7: Standard deviation of the distribution of the proportion of total tree height lost to top-kill (TOPKILL record only).	0.0
MORTMULT (94, S-17)	Enter multiplier to change mortality rate predictions.	
	field 1: Cycle in which multiplier takes effect.	Apply in all cycles
	field 2: Numeric code for species to which multiplier is to be applied.	Apply to all species
	field 3: Mortality multiplier.	1.0
	field 4: d.b.h. of the smallest tree to which multiplier will be applied.	0.0
	field 5: d.b.h. of the largest tree to which multiplier will be applied.	999.0
NOCALIB (90)	Suppress calculation of scale factors for large tree diameter increment model and small tree height increment model.	Calculate scale factors
NOTREES (S-00)	Begin a projection with no tree records. Permits "bare ground" simulations with records generated by the Regeneration Establishment model.	Two tree records must be input or projection will not run
NOTRIPLE (93)	Suppress tree record tripling feature.	Tree records tripled twice
NUMTRIP (93)	Change the number of times tree records will be tripled.	
	field 1: Number of triples.	2.0
RANNSEED (94, S-14)	Reseed the random number generator.	
	field 1: Replacement seed.	55329
READCORD READCORH READCORR (90)	Enter multipliers for the diameter increment model (READCORD), the height increment model (READCORH), or the small tree height increment model (READCORR) that are incorporated prior to model calibration.	

(con.)

Growth Prediction Modifiers and Special Input/Output Options (Con.)

Keyword (page reference)	Keyword use and associated parameters	Default parameter or conditions
	Supplemental record 1: Multipliers for white pine, larch, Douglas-fir, grand fir, western hemlock, western redcedar, lodgepole pine, and Engelmann spruce.	
	Supplemental record 2: Multipliers for subalpine fir, ponderosa pine, and mountain hemlock.	Default value for all multipliers is 1.0
REGDMULT	Parameters same as for BIAMULT.	
REGHMULT	Parameters same as for BIAMULT.	
REUSCORD REUSCORH REUSCORR (91)	Use multipliers that were entered with a READCORD, a READCORH, or a READCORR in a previous projection in the same runstream.	
REWIND (95)	Causes the computer to move the read position pointer to the beginning of the dataset referenced by the unit number entered in field 1. This record is useful when multiple projections are made with the same tree record file in a single runstream.	
	field 1: Dataset reference number.	2
STATS (S-19)	Prepare and print table that describes distribution of input data.	
	field 1: Significance level for computing confidence limits.	0.05
TOPKILL (S-20)	Parameters same as for HTGSTOP.	

Wykoff, William R. Supplement to the user's guide for the Stand Prognosis Model—version 5.0. General Technical Report INT-208. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 36 p.

Differences between Prognosis Model versions 4.0 and 5.0 are described. Additions to version 5.0 include an event monitor that schedules activities contingent on stand characteristics, a regeneration establishment model that predicts the structure of the regeneration stand following treatment, and a COVER model that predicts shrub development and total canopy cover. Program performance has been enhanced by modifications to several of the submodels that predict tree increments.

KEYWORDS: growth and yield, forest management, planning, growth projection, stand models, tree increments, tree mortality

INTERMOUNTAIN RESEARCH STATION

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Vascular Plants of the Desert Experimental Range, Millard County, Utah

Sherel Goodrich



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alph C. Holmgren provided distribution, utilization, d other notes about many of the taxa included, and rt of the introduction was written by him. His collec-ns, knowledge of the plants of the area, and ratorship of the Herbarium of the Desert Experimen- Range has been essential to this treatment.

ESEARCH SUMMARY

Since the establishment of the Desert Experimental ange in 1933, plant specimens have been collected om the area and deposited in the herbarium of the perimental range. These specimens and duplicate ecimens have been sent to botanists acquainted ith various groups of plants for annotation. From this lection of annotated specimens, a checklist of vas-ular plants of the area was assembled. This checklist ovided the basis for the taxa covered in this flora.

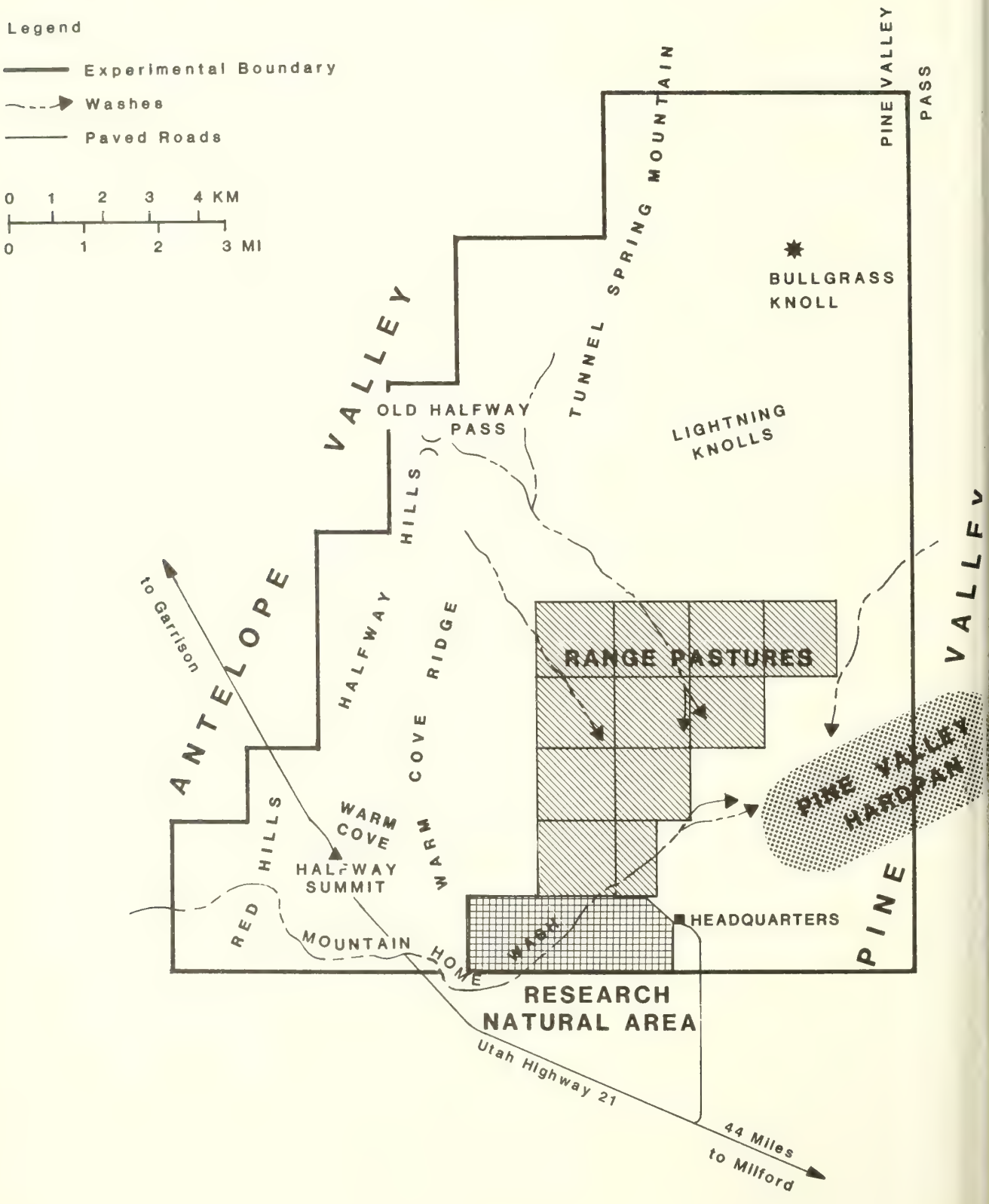
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INTERMOUNTAIN RESEARCH STATION

DESERT EXPERIMENTAL RANGE

SOUTHWEST MILLARD COUNTY, UTAH



Vascular Plants of the Desert Experimental Range, Millard County, Utah

Sherel Goodrich

SECTION I: THE KEYS

INTRODUCTION

The Desert Experimental Range (DER) of the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, is in southwestern Millard County, UT. It consists of about 22 533 ha (55,680 acres) of valley and mountain land typical of some millions of hectares of the eastern part of the cold desert portion of the Great Basin. Since its establishment in 1933, it has been the scene of a number of studies relating to aspects of range management and ecology. This manual is intended to assist current and future studies on the DER by providing identification of plants that grow there and to offer information about the plants such as distribution and importance on the DER.

The keys, descriptions, and other information given apply to plants of the DER only. Outside the DER, plants of a given taxon may vary considerably from the descriptions here. Descriptions of families and particularly of genera are modified to apply only to their members as found on the area, and this treatment, therefore, will be of limited value outside the DER. This narrow approach is followed to keep the work brief and to facilitate the writing of keys based on vegetative features. Descriptive features listed in the keys to families, genera, and species are usually not repeated in the descriptions, and thus descriptions are mostly incomplete. There are several other works that can be referred to for more detailed descriptions including: Cronquist and others (1972, 1977, 1984) and Welsh (1978 to 1983). These two floras, with current nomenclature, deal with broad regions of the Intermountain West including our local area, but they are at present less than half complete. The keys, descriptions, and illustrations in Munz (1968), Hitchcock and others (1955 to 1969), Abrams (1923 to 1960), and Kearney and Peebles (1969) are helpful, but they were written for regions outside of Utah and hence do not include all the plants of the DER. Nomenclature used in studies during the early years of work at the DER for the most part corresponds to that of Tidestrom (1925). Since Tidestrom's time, numerous nomenclatural changes have been made, and many new taxa of our flora have been described. The U.S. Department of Agriculture (1940 to 1965) supported contributions toward a flora of Nevada, a series by several authors that was never completed. That flora has also been used at the DER, and names in some studies have been taken from it. The lack of a complete flora with modern plant names for the area has been the stimulus for this work, which provides a nearly complete listing of plants of the DER. Also, it is intended to provide a synonymy that includes names used by Tidestrom and perhaps other manuals used for plant identification in the past at the DER. It is hoped that the listing of synonymy will aid in consistent interpretation of data gathered over the years by equating the various names that may have been used for the same plant.

In the course of range studies, it is probably more often than not that the worker needs to identify plants in vegetative, fruiting, or early or late flowering stages. Considerable effort was made to design the keys for work with plant specimens at stages other than anthesis. Vegetative features can be extremely variable, and the keys based on vegetative features should be used with caution. However, because the flora of this limited area is small (about 240 taxa), it is feasible to present a vegetative key, and this then becomes another good reason for restricting the work to plants found within the boundary of the DER. For a final check, one should compare keyed vegetative specimens to herbarium specimens. For the most part, the herbarium of the DER (DERM; Holmgren and others 1981) has an adequate to excellent representation of DER plants.

Many of the specimens there have been examined and annotated by botanists specializing in families or genera found on the DER. The present flora is arranged alphabetically by family, genus, and species without regard to phylogenetic order. Several taxa are listed in the keys with authors but are not listed in the descriptions. This procedure was followed for taxa known only from Headquarters (buildings at the south end of the DER) and for a few taxa from areas near to but outside the boundary of the DER.

Notes on distribution and number of taxa listed are based on many years of experience, but neither the distributions nor the listing should be considered complete. New taxa have been added to the list in almost every year that serious collecting has been attempted. There is no reason to believe that all indigenous plants are included, and future introductions should be expected. Notes on grazing use by domestic livestock are based on winter observations only. Domestic livestock have never been kept on the DER in summer, and summer observations of livestock preference have not been possible.

Occupying part of the north end of Pine Valley and extending westward across hills and mountains into Antelope Valley, the DER contains a variety of habitats in its arid landscape. A number of landforms are typical of Great Basin fault-block physiography. The highlands, from south to north, are the Red Hills of Tertiary acidic volcanic rocks; the Halfway Hills, Warm Cove Ridge, and the higher Tunnel Spring Mountain, of Paleozoic sedimentaries—dolomites, quartzite, and limestone—with scattered, small outliers of volcanics. Bedrock is exposed as cliffs and ledges in the steeper parts of the uplands, and the overlying soil materials are thin in many places. In small basins and topographic pockets, as well as on gentler mountain slopes, the loose material may be much thicker than the depth of root penetration.

Skirting the hills and extending well out into the valleys are gravelly-stony bajadas and alluvial fans with slopes ranging between 2 and 8 percent. The land surfaces are obviously of variable age from Late Pleistocene to Recent. The alluvial slopes are cut up by numerous shallow drainageways (or deeper ones extending outward from the canyons). These "dry washes," with gravelly beds, seldom become running streams. They flow only for short periods (minutes or a few hours) after summer rains of high intensity, going years without any flow at all.

The central valley floors are nearly flat and the soil materials there are fine-gravelly or without gravels. Some parts are outwash plains, areas of current accumulation of sediment. In the lowest part of Pine Valley, a valley without exterior drainage, there is a barren playa, an ephemeral lake known as the Pine Valley Hardpan. It is a summer lake, having water (rarely deeper than a few inches) on part or all of its bed for only a few days or weeks after rainy periods, but not every year. Water escapes by evaporation. During the Pluvial period of Late Pleistocene, Pine Valley contained a much larger lake whose evidence is obvious in gravelly-sandy beach terraces, bars, and spits at various levels on the lower bajadas to an elevation of about 46 m (150 ft) higher than the present dry lake bed. The total elevational range on the DER is almost 1 036 m (3,400 ft), from 1 547 m (5,075 ft) on the Pine Valley Hardpan to 2 578 m (8,457 ft) at the highest point of Tunnel Spring Mountain.

The soils range in texture from sandy loams to loamy sands or sands, most but not all of them gravelly. Except for the playa and some limited areas in its neighborhood, they are mostly very low in clay content. They are classed as aridisols and entisols (Calciorthids, Torrifluvents, Torripsamments, and in a few small areas Natrargids). Almost all are nonsaline in the surface 25- to 38-cm (10- to 15-inch) layers, but many are strongly saline at greater depths.

Winters are cold and summers are warm. January mean temperature is −3.5 °C (25.7 °F). For July the mean is 23.1 °C (73.6 °F). The average annual precipitation is about 15.2 cm (6 inches) over most of the DER, with greater amounts, probably as much as 22.9 cm (9 inches), in the higher parts of Tunnel Spring Mountain. The elevational difference is largely due to greater amounts of winter precipitation at the higher altitudes. Monthly averages are highest for July and August, about 1.9 to 2.0 cm (0.75 to 0.80 inch) each. The lowest in winter is between 0.75 and 1.02 cm (0.30 and 0.40 inch) for the months of November, December, January, and February. However, such values are essentially meaningless because any month is likely to be without precipitation or with too little to be effective for plant growth. But over the course of a year the likelihood of effective moisture during some month or other is much greater. Of course, there are extremely dry years and wet (for a desert) years—ranging from 0.4 to 1.9 of average—but never a year in the past 50 without precipitation for at least some plant growth.

Almost every year sufficient soil moisture accumulates over winter to allow the early growing species to start growth in the spring. When the winter has been comparatively dry, these species may not remain active long enough to complete growth through their reproductive phase, unless spring rains occur. Other than during this spring period, when some soil moisture is expected, growth occurs if and when there is sufficient rain to wet the soil to several inches. Approximate times and amounts of precipitation are not predictable; there is not the seasonality of precipitation pattern that a hydrograph of monthly averages would imply.

Some perennial plants respond primarily to warm season moisture and grow with sufficient summer or fall rains. Others respond to the more reliable winter accumulation that permits early spring growth. A few opportunist types take advantage of moisture at both seasons.

Annuals are the extreme case in variability of aspect from year to year. The different species seem to need a moisture-temperature condition at a specific season for germination as well as sufficient moisture subsequently for growth. It is a rare year when all annual species known to be part of the flora are found, and the abundance and vigor of those that are present are also widely variable. Years totally or virtually without winter annuals, without summer annuals, or without any annuals are not uncommon.

A number of perennial plant species of the valley slopes are confined to or within a few feet of dry washes. These usually respond with luxuriant growth after a channel has carried water, and the irrigation effect may show in the following year as well. During the several years between floods, the growth, dependant upon the precipitation received on the site, is much less.

Plant communities on Tunnel Spring Mountain and higher steeper slopes of the area are dominated by singleleaf pinyon (*Pinus monophylla*), Utah juniper (*Juniperus osteosperma*), and littleleaf mountain mahogany (*Cercocarpus intricatus*). Bullgrass (*Elymus ambiguus*), stemless goldenweed (*Haplopappus acaulis*), and rough lomatium (*Lomatium scabrum*) are common associated plants. On Warm Cove Ridge and other hills, pinyon is lacking, juniper is rare, and the mahogany is localized. On these hills black sagebrush (*Artemisia nova*), shadscale (*Atriplex confertifolia*), and other cold desert shrubs are dominant. Greasebush (*Forsellesia nevadensis*) is locally common. Sandberg bluegrass (*Poa secunda*), *Stipa* spp., and Indian ricegrass (*Oryzopsis hymenoides*) are among the common grasses. Forbs are numerous, but among the most common are stemless goldenweed and rough lomatium.

On alluvial fans (referred to in the text as fans) and in valleys, Greene rabbitbrush (*Chrysothamnus greenei*), winterfat (*Ceratoides lanata*), shadscale, Nevada ephedra (*Ephedra nevadensis*), black sagebrush, and other cold desert shrubs are dominant over large areas. Indian ricegrass, sand dropseed (*Sporobolus cryptandrus*), galleta (*Hilaria jamesii*), needle-and-thread (*Stipa comata*), blue grama (*Bouteloua gracilis*), and squirreltail (*Sitanion hystrix*) are common grasses. In places, especially under continuous heavy grazing in winter, some of these grasses are dominant. Gooseberryleaf globemallow (*Sphaeralcea grossulariifolia*) is a common forb. Plant species of fans and valleys mix in seemingly endless combinations to form communities that must, for the most part, be a function of soils.

A number of rather narrowly endemic plants are found on the DER. Most of these are found in hills and upper parts of older fans. The Devonian Sevy Dolomite is especially rich in these endemics. The type specimens of *Eriogonum eremicum, Lesquerella goodrichii, Penstemon concinnis*, and *Penstemon nanus* are from the DER. These are narrow endemics of southwest Millard County and adjacent Beaver County. The type specimen of *Cymopterus basalticus* (from Half Way Station) is most likely from the DER, and the type specimen of *Sphaeralcea caespitosa* is from near the DER. These species are also endemics of about the same distribution as the three taxa listed above. The type specimen of *Atriplex bonnevillensis* is from the area of the Pine Valley Hardpan and possibly from the DER. This plant has rather broad distribution in the Great Basin. *Eriogonum howellianum* and *Haplopappus cervinus* are rather narrow endemics, and *Trifolium andersonii* var. *friscanum* is known only from the San Francisco Mountains and Tunnel Spring Mountain of Millard County. *Cryptantha compacta, Machaeranthera grindelioides* var. *depressa, Opuntia puchella*, and *Sclerocactus pubispinus* var. *pubispinus* are among the several Great Basin endemics of somewhat broader distribution that are found on the DER.

A number of species of warmer or at least more southern distribution seem to have reached a northern limit in the Utah portion of the Great Basin at or near the DER.

Among them are Bigelow sagebrush (*Artemisia bigelovii*), sixweeks grama (*Bouteloua barbata*), spike pappusgrass (*Enneapogon desvauxii*), *Muhlenbergia arsenei*, Whipple cholla (*Opuntia whipplei*), and desert almond (*Prunus fasciculata*). Just off the DER, Nevada broomsage (*Lepidospartum latisquamum*) and Hall panicum (*Panicum hallii*) reach their northern limit, but have not yet been collected on the area itself.

KEY TO FAMILIES

1 Stems with spine-bearing areoles, thickened and filled with spongy, succulent, mucilaginous tissue; leaves lacking or essentially so; flowers showy; petals and stamens numerous (prickly pears and other cacti) ..... CACTACEAE
1 Plants not as above in all features
  2 Plants shrubs or trees, woody well above ground level or if subshrubs not woody above the base then with spine-tipped twigs; leaves not all basal, not with spinulose margins ..... KEY 1
  2 Plants herbaceous above ground level, not spiny or if so then leaves with spinulose or spiny margins (plants with woody bases and basal or nearly all basal leaves are keyed here)
    3 Leaves sheathing the stems; perianth reduced to chaffy scalelike bracts or a sac; plants grasses or grasslike
      4 Stems jointed, often with hollow internodes, with swollen usually solid nodes; flowers mostly bisexual or pistillate; seed (caryopsis) folded between chaffy bracts (lemma and palea) ..... POACEAE
      4 Stems not jointed, solid, nodes not swollen; flowers unisexual, subtended by a single chaffy bract; seed (achene) enclosed in a sac (perigynium) ..... CYPERACEAE
    3 Leaves rarely sheathing the stem except in LILIACEAE, and then the perianth well developed and more or less showy
      5 Plants with neither scapes nor aboveground stems, without flowers, not producing seed, reproducing by spores borne on the lower side of the ultimate segments of pinnately dissected leaves; leaves more or less tufted on a short underground stem ..... POLYPODIACEAE
      5 Plants with scapes or aboveground stems; producing flowers and seeds; leaves compound or simple
        6 Key to plants with flowers at or near anthesis ..... KEY 2
        6 Keys to plants in vegetative condition or with very young, withered, or fallen flowers (keys not designed for use on basal rosettes, but by keying two or more ways, the keys should be helpful in indicating a few taxa that might be checked in the herbarium)
          7 At least some of the lower leaves compound or pinnatifid or palmatifid and cut to the midrib or base ..... KEY 3
          7 Leaves entire, toothed or lobed but not cut to the midrib or base
            8 Leaves toothed or lobed ..... KEY 4
            8 Leaves entire or sometimes very inconspicuously toothed ..... KEY 5

KEY 1: PLANTS WOODY ABOVE THE BASE OR WITH SPINE-TIPPED TWIGS OR BOTH

1 Plants indigenous, not restricted to (but sometimes in) cultivation at Headquarters; shrubs and small trees
  2 Plants evergreen, trees, treelike or occasionally shrubs, mostly over 2 m tall; leaves needlelike or scalelike, with pinelike odor
    3 Leaves scalelike, densely crowded and overlapping, appressed to the twigs, appearing as scaly covering on the twigs, less than 1 cm long; seeds borne in rounded berrylike glaucous cones; cones less than 1.5 cm in diameter ..... CUPRESSACEAE
    3 Leaves needlelike, spreading, not appressed to the twigs, over 1 cm long; seeds borne in cones with several scales ..... PINACEAE
  2 Plants either not evergreen or the leaves not with pinelike odor, shrubs
    4 At least some of the leaves conspicuously and regularly toothed, lobed, or dissected

5 Leaves aromatic with sagebrushlike (camphorlike) odor; densely gray or white pubescent on both sides or pinnately divided to the midrib (*Artemisia*) ..... ASTERACEAE

5 Leaves without odor of sagebrush, green, at least not densely gray- or white-pubescent on the upper side, palmately lobed

6 Leaves divided to the base into 3-7 linear needlelike segments, at least the lower ones opposite, the linear segments sometimes arranged as whorls of needlelike leaves, plants 10-40 cm tall (*Leptodactylon*) ..... POLEMONIACEAE

6 Leaves toothed or lobed, not divided into narrow segments, alternate; plants mostly over 40 cm tall

7 Leaves sessile or very gradually tapered into a petiole 1-5 mm long, the blades fan-shaped or wedge-shaped at the base, 3-15 mm long and mostly 5-lobed with lobes entire, or if larger then with some rather pointed teeth; flowers white to cream, or if yellow then the petals 5-9 mm long; fruit an achene, not red ..... ROSACEAE

7 Leaf blades abruptly constricted to a petiole, at least some of the petioles over 5 mm long, the blades truncate to cordate at the base; flowers pink, or if yellow the petals only 2-3 mm long; fruit a drupe or berry, red or reddish

8 Flowers pink, not appearing before the leaves; petioles pubescent, often glandular, leaf blades with 3-5 rounded lobes, the lobes with several rounded teeth; fruit a berry with more than one seed (*Ribes*) ..... SAXIFRAGACEAE

8 Flowers yellow, appearing before the leaves; petioles glabrous; leaf blades variously lobed or toothed; fruit a dry drupe with one seed (*Rhus*) ..... ANACARDIACEAE

4 Leaves entire, or inconspicuously and irregularly toothed, or lacking

9 Leaves all basal, linear, rigid, swordlike, and evergreen, the margins with exfoliating curled stringlike fibers; flowers showy, 4-6 cm long, pendant ..... AGAVACEAE

9 Leaves not all basal, not as above in all other features; flowers smaller

10 Leaves and twigs opposite, if leaves lacking then twigs opposite or whorled

11 Leaves scalelike, inconspicuous, readily deciduous; twigs whorled, greenish or blue-green ..... EPHEDRACEAE

11 Leaves not scalelike, conspicuous, persistent at least through most of the summer; twigs not or rarely whorled, variously colored

12 Leaves elliptic or linear, sessile or on petioles to 3 mm long; flowers not in heads, not verticillate

13 Leaves all opposite, 6-15 mm long; plants of rocky hills and washes; 50-100 cm tall; flowers conspicuous, corolla united, pink ..... CAPRIFOLIACEAE

13 Upper and sometimes nearly all leaves alternate, sometimes over 15 mm long; plants of valleys, mostly near the Pine Valley Playa; flowers inconspicuous; corolla lacking (*Atriplex*) ..... CHENOPODIACEAE

12 Leaves not elliptic, the blade often about as wide as long, on distinct petioles; flowers various

14 Leaves green, ovate, often toothed, abruptly petioled; twigs green; plants woody only at the very base, not strongly aromatic; flowers borne in heads, the corollas yellow (*Perityle*) ..... ASTERACEAE

14 Leaves gray or gray-green, obovate or broadly oblanceolate, tapered to the petiole; twigs grayish or purplish; plants usually woody well above the base, strongly aromatic; flowers borne in verticils, purplish (*Salvia*) ..... LAMIACEAE

10 Leaves and twigs alternate, sometimes fascicled and falsely appearing opposite or whorled

15 Plants armed with spines; leaves about 3-15 mm long, 1-5 mm wide except sometimes larger in CHENOPODIACEAE, sessile or nearly so and gradually tapered to an indistinct petiole

16 Twigs tomentose or hairs at least in lines; spines with fascicles of leaves (3-5) in the axils and often with globular tufts of matted hairs in the axils; flowers borne in heads; the heads subtended by 4-6 bracts; corollas united, bright yellow, 6-10 mm long, subtended by hairlike bristles (*Tetradymia*) ..... ASTERACEAE

16 Twigs not tomentose except in *Polygala acanthoclada*, the axils of spines without tufts of matted hairs; flowers not in heads; petals free or lacking, not bright yellow, 2-10 mm long, without hairlike bristles

17 Young twigs glabrous to scabrous, greenish or yellow-green; leaves glabrous or scabrous

18 Plants (30) 50-150 cm tall, twigs glabrous, those of the current year succulent at first; leaves linear to terete, succulent (*Sarcobatus*) ..... CHENOPODIACEAE

18 Plants 5-50 cm tall; twigs glabrate to puberulent, not succulent; leaves elliptic to narrowly oblanceolate or obovate, not succulent

19 Plants 5-20 cm tall, rare on the DER; petals 6-10 mm long ..... POLYGALACEAE

19 Plants mostly over 15 cm tall, frequent to common in rocky hills; petals 4-7 mm long, whitish ..... CELASTRACEAE

17 Young twigs scurfy to tomentose, grayish or whitish, not green

20 Leaves scurfy (covered with inflated but quickly collapsing hairs that appear as a dandrufflike covering) at least when young, 10-30 mm long, 5-12 mm wide, linear-oblanceolate, spatulate, obovate or orbicular; twigs sometimes scurfy; flowers inconspicuous; petals lacking ..... CHENOPODIACEAE

20 Leaves not scurfy, 3-15 (25) mm long, 1-4 (6) mm wide, linear to narrowly oblanceolate, rarely broader; twigs glabrate or tomentose, not scurfy; flowers more or less conspicuous; petals present

21 Plants 5-25 (30) cm tall, very spiny; flowers borne on slender pedicels on or near young spines ..... POLYGALACEAE

21 Plants 30-150 cm tall, more or less spiny; flowers sessile or nearly so, not all borne on or near spines ..... ROSACEAE

15 Plants not armed with spines

22 Flowers borne in heads, the heads subtended by separate involucral bracts; corollas yellow, or if greenish then 10-14 mm long; plants often viscid or glandular pubescent at least in part; leaves mostly glabrous or scabrous ..... ASTERACEAE

22 Flowers not borne in heads; corollas white to cream or lacking, not over 5 mm long; plants not viscid or glandular; leaves glabrous, scurfy, scabrous, sericeous, or tomentose

23 Both sides of leaves, young twigs, or both scurfy, sericeous, or tomentose; plants 10-100 cm tall, flowering from spring-fall

24 Inflorescence umbellike or trichotomously branched; flowers small but inconspicuous, the perianth white or pinkish; leaves, young twigs, and branches of the inflorescence tomentose (*Eriogonum*) ..... POLYGONACEAE

24 Inflorescence narrow, spikelike; flowers inconspicuous; plants scurfy, sericeous, or tomentose to woolly .... CHENOPODIACEAE

23 At least the upper surface of leaves glabrous and green or at most puberulent; young twigs glabrate to puberulent; plants 30-150 cm tall, flowering in spring ..... ROSACEAE

1 Plants cultivated or adventive at Headquarters; plants mostly trees

25 Plants evergreen; leaves needlelike or scalelike, aromatic with pinelike odor

26 Plants spreading shrubs, not over 1 m tall; leaves awl-shaped or linear, not over 1 cm long, borne singly (prostrate or common juniper) .. *Juniperus communis* L

26 Plants trees or shrubs over 1 m tall; leaves various

27 Leaves scalelike, crowded, appressed, clothing the twigs, about 2-5 mm long; seeds borne in a berrylike cone, the cone not over 1.5 cm long

28 Plants much branched, the central trunk commonly not much if any larger than the lower primary branches; shrubs or shrublike trees, not over 5 m tall, also native to the DER; fruit (6) 8-14 mm in diameter; ultimate twigs over 1 mm thick ..... *Juniperus osteosperma* (Torr.) Littl

28 Plants with a strong central trunk or trunks much larger than the primary branches, upright narrow-crowned trees, over 5 m tall, not native to DER; fruit 4-8 mm in diameter; ultimate twigs less than 1 mm thick
29 Mature scalelike leaves mostly overlapping the ones directly above; dorsal gland on each leaf much shorter than the distance between the gland and the leaf tip (eastern redcedar) ..... *Juniperus virginiana* L.
29 Mature scalelike leaves seldom overlapping the ones directly above; dorsal gland on each leaf equaling or exceeding the distance between the gland and the leaf tip (Rocky Mountain juniper; Rocky Mountain redcedar) ..... *Juniperus scopulorum* Sarg.
27 Leaves needlelike, 2-3 in a fascicle, 7-20 cm long; seeds borne in woody cones with many overlapping scales, the cones 7-12 (15) cm long (ponderosa pine) ..... *Pinus ponderosa* Laws.
25 Plants not evergreen; leaves not aromatic with pinelike odor, not needlelike, not scalelike except in *Tamarix*
30 Leaves pinnately compound with (5) 11-36 leaflets; fruit a large pod; trees more or less thorny
31 Leaves twice-pinnately compound; flowers regular; petals 3-5, separate, yellowish; stamens 3-10, distinct; pods 7-35 cm long (honey locust) ..... *Gleditsia triacanthos* L.
31 Leaves once-pinnately compound; flowers papilionaceous (with banner, wings, and keel), white; stamens 10, 9 united and 1 free (diadelphous), the united filaments forming a sheath around the ovary; pods 4-12 cm long (black locust) ..... *Robinia pseudoacacia* L.
30 Leaves simple
32 Leaves toothed; trees
33 Leaves slightly oblique at the base; petioles 3-10 mm long; petals lacking (Siberian elm) ..... *Ulmus pumila* L.
33 Leaves obtuse to cordate at the base; petioles 10-30 (40) mm long; petals 8-12 mm long (apricot) ..... *Prunus armeniaca* L.
32 Leaves entire; trees or shrubs
34 Leaves scalelike, not over 4 mm long, appressed to and clothing the twigs; plants shrubs or small trees (salt cedar, tamarisk) (*Tamarix gallica* L. and *T. pentandra* Pall. misapplied) ... *Tamarix ramosissima* Ledeb.
34 Leaves 3-10 cm long, not scalelike, not clothing the twigs; plants trees (Russian olive) ..... *Elaeagnus angustifolia* L.

KEY 2: HERBACEOUS PLANTS WITH FLOWERS AT OR NEAR ANTHESIS

1 Flowers few to numerous in heads, small and by casual observation whole heads appearing as a single flower; heads subtended by an involucre of 1 to several series of separate bracts, the bracts mostly more than 5, seldom over 3 mm wide, mostly equaling and enveloping the flowers; calyx lacking or modified into a pappus of bristles or scales; corollas tubular or flattened and strap-shaped; ovary inferior; sunflowers, daisies, asters, thistles, dandelions, and ragweeds ..... ASTERACEAE

1 Flowers not in involucrate heads or if so then the involucral bracts not more than 5 and mostly over 3 mm wide and mostly shorter than the flowers; calyx lacking or various but not modified into a pappus of bristles or scales; corollas various; ovary inferior or superior
2 Sepals 4, separate; petals 4, separate (appearing united at the base by a long floral tube in ONAGRACEAE); fruit linear to orbicular, a capsule or modified capsule
3 Leaves digitately 3-7 foliate, the leaflets 2-7 cm long; petals purple; stamens exserted well beyond the petals; fruit stipitate ..... CAPPARIDACEAE
3 Leaves simple or pinnately lobed, pinnatifid or pinnately compound
4 Leaves whorled ..... GENTIANACEAE
4 Leaves not whorled
5 Stamens 8; style slender and elongate, usually equaling or exceeding the petals, obviously distinct from the ovary; stigmas discoid or divided into 4 linear lobes; petals 4-40 mm long, borne on a 4-50 mm long floral tube; ovary inferior; plants with simple hairs .... ONAGRACEAE

5 Stamens 6; style various but often obsolete; stigmas entire or slightly bilobed; petals lacking or to 17 mm long; floral tube lacking; ovary superior; plants glabrous or with simple, forked, branched, or stellate hairs ..... BRASSICACEAE

2 Sepals not 4 and separate; petals not 4 and separate; fruit various

6 Flowers sweetpea type (the corolla papilionaceous), the uppermost petal (banner) the largest and more or less turned 90° to the lower ones, the 2 lateral petals (wings) equal and more or less enfolding the lowermost petals (keel) which are united and strongly folded (boat-shaped); leaves trifoliate or once-pinnate compound or once-palmate compound; the leaflets well marked, entire or finely toothed, jointed to the rachis or petiole ..... FABACEAE

6 Flowers not as above; leaves rarely with the above combination of features

7 Leaves all basal (some pulvinate caespitose plants with leaves only appearing all basal are keyed both ways)

8 Leaves toothed, lobed or compound

9 Corolla united 2-5 cm long, very irregular (*Pedicularis*) ..... SCROPHULARIACEAE

9 Corolla not united, less than 2 cm long, regular

10 Flowers solitary and terminal; petals about 12-15 mm long, reddish or pink-purple; leaves palmately cut ..... RANUNCULACEAE

10 Flowers usually more than 1; petals not over 7 mm long, variously colored; leaves various

11 Leaves palmately lobed less than half the way to the base; inflorescence a spicate or racemose panicle (*Heuchera*) ..... SAXIFRAGACEAE

11 Leaves ternate or pinnately cut, mostly more than half the way to the base

12 Petals pinkish, about 5-7 mm long; flowers not in umbels ..... GERANIACEAE

12 Petals white or yellow, 1-3 mm long; flowers in compact headlike or open umbels ..... APIACEAE

8 Leaves simple and entire

13 Scapes lacking; flowers sessile among the leaves, not in heads; leaves mostly 3-6 mm long, opposite, crowded on short stems and more or less appearing basal, sessile; plants mat or mound forming

14 Flowers showy, exceeding the leaves; leaves not subtended by scarious stipules; plant rather densely pubescent with cobwebby hairs or some leaves over 6 mm long (*Phlox*) ..... POLEMONIACEAE

14 Flowers inconspicuous, hidden among the leaves; corolla lacking; leaves 3-6 mm long, subtended by scarious stipules about as long as the leaves; plants glabrous or puberulent ... CARYOPHYLLACEAE

13 Scapes or peduncles present, sometimes short; leaves mostly over 6 mm long or flowers in heads; leaves all basal, or peduncles sometimes with bractlike leaves; plants various

15 Flowers with 6 separate petaloid tepals, mostly 7-60 mm long; stamens 6

16 Flowers 4-6 cm long, pendulous, in racemes; leaves rigid, swordlike, evergreen, often with curled fibers shredding from the margins, 10-50 cm long or longer; plants from woody caudices ..... AGAVACEAE

16 Flowers not over 1.5 cm long, in umbels or if in racemes then not pendulous; leaves not rigid, not swordlike, not evergreen, without shredding fibers, seldom over 10 cm long; plants from bulbs ..... LILIACEAE

15 Flowers either with united corolla or with 4 or 5 or more than 6 separate petals or petals lacking; sepals 4 or 5 or calyx united or lacking; stamens not 6

17 Flowers solitary and terminal on a jointed scape, the scape with a whorl of scarious bracts subtending the joint; petals more than 10, 10-35 mm long; stamens 20-50; leaves fleshy, 1.5-3 (5) cm long; plants rare ..... PORTULACACEAE

17 Flowers not solitary as above, in heads or in an open inflorescence; scapes not jointed, without a whorl of bracts; petals lacking, the petaloid perianth united, 2-15 mm long; stamens 4, 5, or 9
18 Plants perennial with woody creeping stems, growing on rock faces, flowering in August and September (*Petrophytum*) ... ROSACEAE
18 Plants annual or if perennial then flowering in spring and early summer
19 Flowers 11-15 mm long, sessile, several together in heads, the heads subtended by scarious bracts; leaves glabrous, glaucous; plants perennial (*Abronia nana*) .. NYCTAGINACEAE
19 Flowers 2-6 mm long, few together in small united involucres, pediceled, the slender pedicel included or exserted from the involucres; inflorescence open or congested into a head; leaves hairy; plants annual or perennial ..... POLYGONACEAE

7 Leaves not all basal
20 Flowers spurred, sepals and petals blue and of equal texture; leaves alternate, palmatifid, the primary divisions again lobed (*Delphinium*) ..... RANUNCULACEAE
20 Flowers not spurred, variously colored; leaves various
21 Perianth of united corolla or calyx
22 Plants lacking chlorophyll, whitish or pale reddish, not at all green, more or less fleshy, parasitic on roots of other plants; leaves bract-like, entire ..... OROBANCHACEAE
22 Plants with chlorophyll more or less greenish or sometimes covered with whitish or grayish hairs, not fleshy, not parasitic; leaves various
23 Leaves opposite or whorled
24 Leaves whorled, mostly 4 per node ..... RUBIACEAE
24 Leaves opposite
25 Leaves irregularly toothed and cleft, often with 1 or 2 pairs of pinnatifid primary lower segments that are smaller than the terminal one; flowers about 5 mm long, more or less hidden in entire lance-linear bracts; plants annual or perennial, introduced, occasional weed at Headquarters, mostly along roads (vervain or verbena) ..... *Verbena bracteata* Lag. & Rodr.
25 Leaves not as above; flowers various
26 Flowers regular (symmetrical) or nearly so
27 Leaves sessile, linear or divided into linear segments, not over 5 mm wide or the segments not over 2 mm wide; styles divided into 3 linear lobes . POLEMONIACEAE
27 Leaves not sessile or at least not linear, mostly over 5 mm wide; styles entire ..... NYCTAGINACEAE
26 Flowers more or less irregular, the corolla at least 2-lipped
28 Stems gray or white with woolly hairs, or if only puberulent then the leaves only 5-15 mm long and 1-4 mm wide; stems square in cross section; corollas 5-12 mm long ..... LAMIACEAE
28 Leaves glabrous or puberulent, at least some well over 15 mm long; stems not square in cross section; corollas 8-35 mm long (*Penstemon*) ..... SCROPHULARIACEAE
23 Leaves alternate
29 Plants trailing or climbing, probably restricted to irrigated places at Headquarters; leaves usually hastate-lobed, some usually over 2 cm long; corollas 1-3 cm wide (wild morning glory; field bindweed) ..... *Convolvulus arvensis* L.
29 Plants not trailing or climbing, sometimes prostrate, but then the leaves not over 16 mm long, not restricted as above; leaves not hastate-lobed; corollas various
30 Leaves simple, entire; plants with rather harsh nonviscid and nonglandular hairs; styles 1, entire; fruit of 1-4 nutlets ..... BORAGINACEAE

30 Leaves toothed to pinnately lobed or pinnatifid, or if entire then styles 2-3 or 2-3-cleft; fruit a capsule; plants often with viscid or gland-tipped hairs
31 Styles 1 entire; stamens 4; corolla irregular, 16-35 mm long, reddish or purplish ..... SCROPHULARIACEAE
31 Styles 2 or 3 or 2-3-cleft; stamens 5; corolla regular, 2-12 (15) mm long, whitish, blue, pinkish, sometimes with a yellow tube
32 Styles 2 or 2-cleft; flowers borne in a coiled one-sided racemose inflorescence that uncoils as the flowers mature (a scorpioid cyme) ..... HYDROPHYLLACEAE
32 Styles 3 or 3-cleft; flowers axillary or in a congested headlike or an open paniculate inflorescence, not in a scorpioid cyme ..... POLEMONIACEAE
21 Perianth of separate petals and sepals or the petals lacking or rarely united at the base
33 Tepals 6 or sepals 3 and petals 3; stamens 6; leaves sessile, linear, parallel veined, often more or less sheathing; plants from bulbs, the bulbs often deep in the ground and often missed in collecting ..... LILIACEAE
33 Petals or sepals or both in sets of 4 or 5; stamens not 6; leaves various but seldom with the above combination of features; plants not from bulbs
34 Perianth of a single whorl, the tepals not over 3 mm long
35 Plants pulvinate caespitose; leaves 3-6 mm long, densely crowded concealing the stems, subtended by scarious stipules about as long as the leaves; flowers sessile, more or less hidden in the leaves (*Paronychia*) ..... CARYOPHYLLACEAE
35 Plants not as above in all features
36 Leaves opposite or whorled, 3-20 mm long; fruit various
37 Leaves whorled, 4 per node; plants without milky juice ..... RUBIACEAE
37 Leaves opposite, 2 per node; plants with milky juice ..... EUPHORBIACEAE
36 Leaves alternate; fruit one-seeded; seeds often shiny
38 Leaves with sheathing scarious stipules (*Polygonum*) ..... POLYGONACEAE
38 Leaves without sheathing stipules
39 Flowers obscured among many dry scarious persistent bracts; sepals scarious; leaves not scurfy nor pilose; plants occasional or rare weeds at Headquarters ..... AMARANTHACEAE
39 Flowers not obscured by scarious bracts; sepals various; leaves scurfy or pilose ..... CHENOPODIACEAE
34 Perianth of two whorls (both petals and sepals present), the sepals of different texture and color from the petals; petals mostly over 3 mm long except in *Petrophytum*
40 Leaves opposite or whorled
41 Leaves pinnately compound; petals pink; fruit with a stylar beak 1-5 cm long ..... GERANIACEAE
41 Leaves simple; petals not or rarely pink; fruit not beaked
42 Leaves whorled, 3-4 per node, not needlelike ..... GENTIANACEAE
42 Leaves opposite, 2 per node, needlelike ..... CARYOPHYLLACEAE
40 Leaves alternate
43 Leaves mostly basal, those of the scapelike peduncle 1-3 mm wide (*Petrophytum*) ..... ROSACEAE
43 Leaves not all basal, those of the stem well over 3 mm wide
44 Petals white, 2-5 cm long; stamens numerous; plants prickly-hispid and spinulose, 30-80 (100) cm tall ..... PAPAVERACEAE

44 Petals not white; stamens various; plants neither prickly-hispid nor spinulose, of various stature
45 Petals orange; stamens numerous, the filaments united into a sheath that surrounds the 10-14 styles; plants glabrate to tomentose with stellate hairs; leaves pinnately lobed to palmately divided ..... MALVACEAE
45 Petals blue or yellow; stamens 5-numerous, not united; styles 1 or 5; plant not with stellate hairs; leaves various but not palmately divided
46 Leaves entire, glabrous, glaucous; petals blue or rarely yellow, 10-15 (20) mm long; stamens 5; styles 5 ..... LINACEAE
46 Leaves toothed to deeply lobed, pubescent with retrorsely barbed clinging hairs; petals yellow, 2-6 mm long and stamens 5, or 25-80 mm long and stamens numerous; styles 1 ..... LOASACEAE

KEY 3: HERBACEOUS PLANTS WITH LEAVES COMPOUND, PINNATIFID, OR PALMATIFID

1 Leaves once compound with well marked leaflets; leaflets jointed to the rachis or petiole, not at all confluent
2 Leaves 3-7-foliate, leaflets entire, 1-7 cm long; plants 30-80 cm tall, caulescent, annual ..... CAPPARIDACEAE
2 Leaves not as above, if 3-foliate then the leaflets toothed or lobed; plant not as above except in *Melilotus* (FABACEAE)
3 Leaflets 3, ovate to orbicular, toothed to lobed; leaves all basal; stipules lacking; inflorescence an umbel (*Cymopterus*) ..... APIACEAE
3 Leaflets either more than 3, or entire, or leaves not all basal; stipules well developed; inflorescence not an umbel
4 Leaflets toothed to lobed, several; leaves pinnate, opposite and basal or rarely all basal ..... GERANIACEAE
4 Leaflets entire or if toothed then only 3; leaves alternate and basal or all basal ..... FABACEAE
1 Leaves more than once compound or 1-3 times pinnatifid with more or less confluent segments that are not jointed to the rachis or petiole
5 Leaves palmately cut, or if trifid then the 3 segments entire and filiform or linear; plants perennial except in *Cordylanthus* (SCROPHULARIACEAE)
6 Leaves divided into 3-7 entire, filiform or linear segments, sessile or with an indistinct petiole
7 Plants with viscid-villous hairs; leaf-segments not needlelike with a tiny mucronate point ..... SCROPHULARIACEAE
7 Plants glabrate to tomentose but not with viscid-villous hairs; leaf segments needlelike and with a tiny mucronate point ..... POLEMONIACEAE
6 Leaves divided into 3 or more primary segments that are again toothed or lobed, abruptly contracted to a distinct petiole
8 Plants with scattered to dense stellate hairs ..... MALVACEAE
8 Plants glabrous or with simple hairs only ..... RANUNCULACEAE
5 Leaves pinnately cut or if trifid then the 3 primary segments toothed to lobed
9 Plants more or less tomentose to woolly at least in part, without stipitate glandular hairs; flowers in heads or in a headlike inflorescence
10 Leaves with 3-7 segments, less than 2 cm long, the segments entire, linear, not over 1 cm long; calyx united, tubular (*Gilia congesta*) ..... POLEMONIACEAE
10 Leaves with few to several segments, the segments not linear and entire, or if so, then some usually over 1 cm long; calyx modified into a pappus of separate scales (*Chaenactis, Hymenopappus*, and *Hymenoxys richardsonii*) ..... ASTERACEAE
9 Plants not tomentose, with some cobwebby hairs in *Gilia inconspicua* but then also with stipitate-glandular hairs in the inflorescence

11 Plants with milky juice, glabrous or stipitate glandular; flowers borne in heads, enveloped in an involucre of bracts; involucre not spinulose; calyx modified into a pappus of numerous capillary whitish bristles, the bristles more or less persistent on the seeds (achenes) (*Malacothrix, Prenanthella, Stephanomeria*, and *Taraxacum*) ..... ASTERACEAE

11 Plants without milky juice; flowers not in heads except in *Ambrosia* with spinulose involucres; calyx not as above

12 Leaves all basal, decompound or at least dissected into numerous fine segments; plants perennial; flowers borne in scapose umbels .... APIACEAE

12 Leaves not all basal or if so plants annual; flowers not in scapose umbels

13 Plants stellate pubescent (*Descurainia*) ..... BRASSICACEAE

13 Plants not stellate pubescent

14 Plants 25-80 cm tall or taller, glabrous and glaucous, or pilose; at least the lower leaves 3-14 cm long, the upper ones sometimes entire; fruit 3-14 cm long, linear (*Caulanthus* and *Stanleya*) ..... BRASSICACEAE

14 Plants 3-30 cm tall, glabrous, or variously pubescent; leaves various but seldom as above in all features; fruit mostly less than 3 cm long, linear or not

15 Plants perennial, with viscid-villous hairs at least in the inflorescence, not stipitate-glandular (*Castilleja*) .... SCROPHULARIACEAE

15 Plants annual, if viscid-villous then also mostly stipitate-glandular also

16 Plants stipitate-glandular or some of the leaf segments ending in a tiny mucronate point, or both; herbage often with a skunklike odor, occasionally villous or with cobwebby hairs

17 Neither the lobes nor the teeth of lobes of leaves ending in a mucronate point; plants without tomentum; flowers in a coiled racemose inflorescence that uncoils as the flowers mature (scorpioid cyme) ..... HYDROPHYLLACEAE

17 At least some of the lobes or teeth of the lobes of leaves ending in a tiny mucronate point; leaves stipitate-glandular or not; plants sometimes with some tomentum; inflorescence headlike to open but not a scorpioid cyme .. POLEMONIACEAE

16 Plants not stipitate-glandular; leaf segments not ending in a mucronate point; herbage without a skunklike odor, neither villous nor with cobwebby hairs

18 Stems few to several, decumbent radiating out from the taproot, each with 3 or more pairs of opposite leaves; leaves with 1 or 2 pairs of pinnatifid primary lower segments that are smaller than the terminal one; inflorescence strongly bracteate, the bracts entire; plants introduced, weedy, known from about Headquarters ..... *Verbena bracteata* Lag. & Rodr.

18 Stems solitary or few, mostly erect or ascending, with alternate leaves or with 1-3 pairs of opposite leaves; leaves not as above in all features; plants not restricted as above

19 Terminal part of leaves not as regularly or as deeply cut as the lower part, and often only toothed to entire (*Camissonia*) ..... ONAGRACEAE

19 Leaves about equally cut from base to tip

20 Leaves once pinnately compound with toothed to lobed leaflets, with conspicuous stipules; stem-leaves opposite; basal rosette well developed ..... GERANIACEAE

20 Leaves once or twice pinnatifid; stipules lacking; stem leaves alternate or if a few of the lower ones opposite, then the basal rosette lacking

21 Plants 2-15 (20) cm tall, glabrous to hirtulose with short hairs, flowering in spring; basal rosette well developed; leaves once pinnatifid, to 1 cm wide; fruit not burlike (*Lepidium*) ..... BRASSICACEAE

21 Plants (10) 15-30 cm tall, with spreading strigose and hirsute hairs, flowering in fall; at least some of the leaves bipinnatifid, mostly over 1 cm wide; basal rosette lacking; fruit enclosed in a burlike involucre with 8-20 short spines (*Ambrosia*) ..... ASTERACEAE

KEY 4: HERBACEOUS PLANTS WITH LEAVES SIMPLE AND TOOTHED OR LOBED

1 At least some of the leaves with spiny or spinulose margins
  2 Stems prickly with harsh spreading hairs; plants not floccose or tomentose... ..... PAPAVERACEAE
  2 Stems not prickly or if so then plants floccose or tomentose at least in part (*Cirsium* and *Machaeranthera*) ..... ASTERACEAE
1 Leaves without spinulose margins
  3 Plants with forked, branched, or stellate hairs, or leaves sessile and auriculate clasping at the base, not uniformly toothed from base to tip, or plants with both hairs and leaves as preceding; flowers not in resinous heads
    4 Plants perennial; leaves not auriculate, with rounded teeth or lobes, densely stellate pubescent, the dense hairs giving a whitish or grayish color to the leaves ..... MALVACEAE
    4 Plants annual, or if perennial then leaves auriculate; leaves variously toothed, glabrous to variously pubescent, but the hairs rarely so dense as to color the herbage (*Camelina*, *Draba*, *Malcolmia*, and *Streptanthus*)..... ..... BRASSICACEAE
  3 Plants glabrous or with simple hairs; leaves sessile or petioled but not auriculate, or if auriculate then flowers in resinous heads and leaves uniformly toothed from base to tip
    5 Leaves orbicular or nearly so, all basal, strongly dentate and sometimes palmately lobed as well, rounded to cordate at the base, abruptly contracted to a distinct petiole, the petiole often as long or longer than the blade
      6 Plants glabrous and glaucous, of fans and hills; inflorescence an umbel (occasional specimens of *Cymopterus basalticus*) ..... APIACEAE
      6 Leaves hirsute-ciliate; plants sometimes otherwise pubescent or glandular, not glaucous, of rock crevices (*Heuchera*) ..... SAXIFRAGACEAE
    5 Leaves narrower than orbicular or not all basal, seldom strongly dentate (except in *Atriplex rosea*), not palmately lobed, sessile or gradually tapered to a petiole
      7 Leaves with dense retrorse-barbed minute hairs, clinging to clothing and other porous and even nonporous objects ..... LOASACEAE
      7 Leaves without retrorse-barbed hairs
        8 Leaves toothed or with a pair of hastate lobes, not strongly pinnately lobed; plants annual or perennial, with or without a basal rosette
          9 Stems prostrate, trailing, or climbing
            10 Plants restricted to irrigated areas at Headquarters, trailing, twining, or climbing, not with milky juice; leaves often with a pair of hastate lobes (field bindweed, wild morning glory) (see also *Amaranthus blitoides*) ..... *Convolvulus arvensis* L.
            10 Plants native, prostrate, with milky juice; leaves toothed near the apex ..... EUPHORBIACEAE
          9 Stems lacking or not as above, mostly ascending to erect
            11 Plants tomentose to woolly
              12 Leaves opposite, petioled, crenate; stems more or less square in cross section; plants from taproots (*Marrubium*) ..... LAMIACEAE
              12 Leaves alternate, sessile or gradually tapered to a narrowed base, serrate or dentate to lobed; stems not square in cross section; plants from rhizomes (*Artemisia ludoviciana*) ... ASTERACEAE
            11 Plants not tomentose or woolly
              13 Plants perennial, from long-lived bases, sometimes glandular; leaves basal, opposite or alternate

14 Leaves all basal, not glandular, grayish or whitish from dense hairs; stems lacking; flowers sessile in the basal rosette of leaves, with a long floral tube (*Oenothera*) ..... ONAGRACEAE

14 Leaves alternate or opposite, not grayish or whitish from dense hairs; stems well developed; flowers various but not sessile in the basal rosette

15 At least some of the upper leaves alternate; flowers borne in heads, yellow at least in the center of the heads ..... ASTERACEAE

15 Leaves all opposite; flowers not in heads, not yellow

16 Stem leaves sessile or gradually tapered to an inconspicuous petiole; plants glabrous or nearly so except sometimes with viscid hairs in the inflorescence (*Penstemon*) ..... SCROPHULARIACEAE

16 At least some of the stem leaves with distinct petioles; plants glandular pubescent almost throughout (*Oxybaphus*) ..... NYCTAGINACEAE

13 Plants annual, not glandular except in *Gilia*, leaves alternate or rarely all basal or a few lower ones opposite in *Helianthus*

17 Plants glandular, sometimes densely hairy also, seldom over 10 cm tall (*Gilia*) ..... POLEMONIACEAE

17 Plants not glandular, or regularly over 10 cm tall, not densely hairy, of various stature

18 Plants 2-5 cm tall, hirtulose or hirsute; leaves not hastate, all alternate (*Lepidium*) ..... BRASSICACEAE

18 Plants either taller or with some of the leaves hastate, hispid or scurfy

19 Leaves alternate, more or less constricted to petioles, mostly less than 2.5 cm long, not sessile and auriculate, the blades rarely uniformly toothed from base to apex, the teeth not sharp; plants glabrous or scurfy, not resinous; flowers not in heads, not yellow, inconspicuous ..... (see lead 39 in KEY 2)

19 Either the lower 1 or 2 pairs of leaves opposite and on petioles 2.5-4 cm long or longer or the stem-leaves sessile and more or less auriculate, the blades often uniformly toothed from base to apex; plants short-hairy or very resinous; flowers in heads, at least some yellow, conspicuous ..... ASTERACEAE

8 Leaves conspicuously pinnately lobed; plants mostly annual; basal rosette usually well developed

20 Plants with milky juice; flowers borne in heads, the heads of flowers enveloped in involucral bracts, with numerous capillary pappus bristles ..... ASTERACEAE

20 Plants without milky juice; flowers not in heads, not with pappus bristles

21 Plants (25) 30-100 cm tall; stems glabrous, glaucous, and strongly inflated or strongly hispid-pilose with spreading hairs and not inflated; fruit 7-14 cm long, linear (*Caulanthus*) ..... BRASSICACEAE

21 Plants mostly less than 30 cm tall; stems not inflated, not hispid-pilose; fruit less than 7 cm long, linear or not

22 Plants perennial; lobes of leaves with whitish-margined dentate teeth; inflorescence usually overtopped by the leaves, with some villous, viscid, multicellular hairs (*Pedicularis*) ..... SCROPHULARIACEAE

22 Plants annual or winter annual; lobes of leaves not with whitish-margined dentate teeth; inflorescence exceeding the leaves

23 Leaves deeply lobed toward the base, toothed to nearly entire toward the tip (*Camissonia*) ..... ONAGRACEAE

23 Most of the leaves about equally lobed from the base to the tip

24 Leaves densely glandular, many of the glands stipitate; lobes of the leaves rounded, with crenate teeth; plants glandular throughout, conspicuously malodorous ..... HYDROPHYLLACEAE

24 Leaves not or sparsely glandular; lobes of the leaves acute, entire or with serrate or dentate teeth; plants various, but weakly if at all malodorous

25 Stems and branches of the inflorescence glandular, many of the glands stipitate; at least a few of the lobes of leaves ending in a tiny mucronate tooth (*Gilia*) ..... POLEMONIACEAE

25 Stems and branches of the inflorescence glabrate or hirsute but not glandular; lobes of leaves not ending in a mucronate tooth (Lepidium) ..... BRASSICACEAE

KEY 5: HERBACEOUS PLANTS WITH LEAVES SIMPLE AND ENTIRE OR INCONSPICUOUSLY TOOTHED

1 Plants pubescent with at least some forked, branched or stellate or pick-shaped (malpighian) hairs ..... BRASSICACEAE

1 Plants glabrous or with simple hairs only

2 Plants pulvinate caespitose perennials, mat or mound forming, 2-5 cm tall; leaves 2-6 mm long, densely crowded

3 Plants with obvious scapes; leaves all basal; leafy stems lacking; peduncles sometimes with reduced bracts; herbage densely pubescent; flowers borne in heads or headlike clusters ..... (see lead 12 below)

3 Plants without scapes; leaves crowded on short stems, opposite; herbage glabrous or pubescent; flowers sessile among the leaves

4 Leaves subtended by scarious stipules, the stipules a half to about as long as the leaves (*Paronychia*) ..... CARYOPHYLLACEAE

4 Leaves without scarious stipules (*Phlox*) ..... POLEMONIACEAE

2 Plants not pulvinate caespitose, or if so then some of the leaves longer than 6 mm

5 Leaves all basal; plants perennial except in some of *Eriogonum*

6 Plants glabrous; leaves sessile, linear or gradually tapered to the tip

7 Leaves rigid, swordlike, evergreen, often with curled fibers shredding from the margins, 10-50 cm long; flowers 4-6 cm long, pendulous ..... AGAVACEAE

7 Leaves not rigid, not swordlike, not evergreen, the margins not with shredding fibers, often shorter than above; flowers smaller

8 Plants from bulbs; leaves 1 or 2, or if more than 2 then some over 6 cm long ..... LILIACEAE

8 Plants not from bulbs; leaves more than 2, not over 6 cm long

9 Leaves terete or nearly so, succulent, not at all viscid; plants from a cluster of roots, rare ..... PORTULACACEAE

9 Leaves flattened, not succulent, often more or less viscid; plants from a woody caudex, common (*Haplopappus acaulis*) .. ASTERACEAE

6 Plants conspicuously pubescent at least in part, the leaf blades sometimes glabrous but then abruptly constricted to a petiole

10 Leaves 3-20 mm long, including petioles if present, 1-5 mm wide; plants pulvinate

11 Woody creeping stems over 2 cm long; plants flowering in the fall, growing on faces of rock outcrops; scapose-peduncles bracteate (*Petrophytum*) ..... ROSACEAE

11 Woody stems not as above; plants flowering in spring, on but not confined to rock faces; scapes not bracteate

12 Leaves 4-20 mm long, at least some regularly over 10 mm long, 0.6-1.4 mm wide, strigose; scapes 2-10 cm tall (*Erigeron compactus*) ..... ASTERACEAE

12 Leaves 2-8 mm long, some usually over 1.4 mm wide, tomentose or densely villose; scapes 1-5 cm tall (*Eriogonum shockleyi* and *E. villiflorum*) ..... POLYGONACEAE

10 At least some of the leaves over 20 mm long, including the petioles if present, often over 5 mm wide; plants various
13 Leaves linear, narrowly elliptic, narrowly oblanceolate to elliptic, sessile or gradually tapered to a petiole
14 Caudex surmounted by a tuft of woolly hair and by a scape as well as the leaves; flowers borne in a solitary head that is terminal on the scape, yellow; leaves 2-8 mm wide (*Hymenoxys acaulis*) ..... ASTERACEAE
14 Caudex without tufts of woolly hairs; scape lacking; flowers sessile in the basal rosette, but with a 4-10 cm long floral tube; corolla white or pink when fresh, opening at night, withering within a few hours after daylight the next day (*Oenothera caespitosa*) ..... ONAGRACEAE
13 Leaves ovate to orbicular, rather abruptly tapered to a petiole
15 Scapes and petioles usually glandular; plants perennial, not tomentose; flowers in heads subtended by 5 scarious involucral bracts, the perianth 15-20 mm long, well exceeding the bracts ..... NYCTAGINACEAE
15 Plants not glandular, if perennial then at least the leaves tomentose; flowers in heads or not
16 Leaves (including the petiole) 6-10 cm long; plants perennial from long-lived caudices; flowers borne in heads; scapes (10) 15-30 cm tall (*Enceliopsis*) ..... ASTERACEAE
16 Leaves (including the petiole) less than 6 cm long; plants annual or perennial; flowers not in heads, or if so then scapes rarely over 15 cm tall (*Eriogonum*) ..... POLYGONACEAE
5 Leaves not all basal; plants perennial or annual
17 Leaves opposite or whorled; plants perennial or leaves mostly with well-marked petioles
18 Leaves whorled with more than 2 per node, sessile
19 Leaves 5-20 mm long; plants puberulent ..... RUBIACEAE
19 Leaves 20-80 mm long; plants glabrous
20 Leaves over 7 mm wide, all whorled ..... GENTIANACEAE
20 Leaves 2-7 mm wide, not all whorled (*Fritillaria*) ..... LILIACEAE
18 Leaves opposite, only 2 per node
21 Leaves linear to narrowly elliptic, not over 5 mm wide, sessile
22 Flowers and fruit on slender pedicels, not borne in the axils of leaves; the corolla of separate petals; leaves needlelike, less than 1 mm wide, glabrous or nearly so, lower stem glabrous or nearly so; inflorescence glandular, some of the glands stipitate (*Arenaria*) ..... CARYOPHYLLACEAE
22 Flowers sessile or nearly so or some leaves over 1 mm wide or pubescent or both; corolla united
23 Flowers whorled in the axils of leaves, on pedicels about 2 mm long; plants strongly aromatic, moderately pubescent with short curved hairs (*Hedeoma*) ..... LAMIACEAE
23 Flowers terminal or nearly so or sessile or pediceled; plants not aromatic, glabrous to pubescent with various kinds of hairs (*Phlox*) ..... POLEMONIACEAE
21 At least some of the leaves broader than narrowly elliptic, less than or greater than 5 mm wide, at least the basal ones more or less constricted to a distinct petiole
24 Leaves (including petioles) 3-16 mm long, the blades more or less oblique at the base; plants with milky juice, with prostrate spreading stems ..... EUPHORBIACEAE
24 At least some of the leaves over 16 mm long; plants without milky juice; stems not prostrate
25 Plants tomentose to woolly at least in part; stems more or less square in cross section (*Marrubium*) ..... LAMIACEAE
25 Plants glabrous or pubescent but not tomentose or woolly
26 Plants annual, 30-60 cm tall or taller, scabrous, or hispid; upper leaves usually alternate (*Helianthus*) ..... ASTERACEAE

26 Plants perennial, mostly less than 30 cm tall; upper as well as lower stem-leaves opposite
27 Stem-leaves sessile, sometimes clasping the stem at the base; plants glabrous and glaucous to puberulent or villose with viscid hairs, with a basal tuft of leaves (*Penstemon*) ..... SCROPHULARIACEAE
27 Stem-leaves more or less abruptly constricted to a petiole, this sometimes short; plants glabrous, glandular or stipitate glandular; basal tuft of leaves lacking or present ..... NYCTAGINACEAE
17 Leaves alternate; plants annual or perennial, mostly with sessile leaves, or the blades gradually tapered to an indistinct petiole
28 Plants lacking chlorophyll, pale pink to whitish, not at all green, parasitic on roots of other plants; stems thickened, more or less fleshy; leaves scalelike ..... OROBANCHACEAE
28 Plants with chlorophyll, greenish or pale colored from dense pubescence, not parasitic; stems not especially thickened, not fleshy; leaves various but hardly scalelike
29 At least some of the leaf blades elliptic to broadly ovate, at least some more or less abruptly constricted to a distinct petiole
30 Plants rather uniformly pubescent with villose or appressed hairs, 3-15 cm tall, rarely taller; leaf blades 4-15 mm long
31 Plants glandular and villose rare, in hills; at least some of the petioles about as long as the broadly elliptic to ovate blades (*Phacelia incana*) ..... HYDROPHYLLACEAE
31 Plants with appressed hairs, not glandular; petioles much shorter than the elliptic blades, not over 4 mm long, some leaves sessile (*Camissonia boothii*) ..... ONAGRACEAE
30 Plants glabrous to scurfy or hispid, often over 15 cm tall; leaf blades often over 15 mm long
32 Plants glabrous or more or less scurfy ..... (see lead 39 of KEY 2)
32 Plants scabrous or hispid (*Helianthus*) ..... ASTERACEAE
29 Leaf blades linear, narrowly oblanceolate or narrowly spatulate, sessile or gradually tapered to an indistinct petiole
33 Plants glabrous or at most scabrous
34 Plants annual, from taproots, sometimes much branched at the base (note: odd specimens of *Lepidium densiflorum* might be keyed here, but in plants of that taxon at least 1 or 2 leaves have lobes or teeth)
35 Leaves not over 2 mm wide; fruit with a horizontal wing (*Halogeton* and *Salsola*) ..... CHENOPODIACEAE
35 Leaves 1-12 mm wide, some always over 2 mm wide, 1.5-8.5 cm long; fruit not winged
36 Fruit linear, 3-6 cm long, many-seeded; plants erect (*Streptanthella*) ..... BRASSICACEAE
36 Fruit not linear, less than 0.5 mm long, 1-seeded; plants prostrate to decumbent (*Amaranthus*) .. (see lead 39 of KEY 2)
34 Plants perennial, from bulbs or caudices, the stems simple or sparingly branched
37 Leaves 1-3 cm long, well distributed on the stem, basal tufts lacking or weakly developed ..... LINACEAE
37 At least some of the leaves over 3 cm long, basal tuft lacking or well developed, often crowded toward the base of the stem
38 Leaves strongly sheathing or the basal tuft lacking; plants from bulbs, not at all viscid, rare on DER ..... LILIACEAE
38 Leaves not sheathing, the basal tuft well developed; plants from woody caudices, often viscid, rare to abundant on the DER (*Haplopappus acaulis* and *Petradoria*) ..... ASTERACEAE

33 Plants pubescent or scurfy
39 Flowers borne in heads, the heads subtended by more or less persistent involucral bracts; fruit an achene, the achenes surmounted by a pappus of capillary bristles (*Erigeron, Leucelene,* and *Townsendia*) ..... ASTERACEAE
39 Flowers not in heads; fruit not as above (note: odd specimens of *Lepidium densiflorum* might be keyed here but at least 1 or 2 leaves are toothed or lobed in plants of that taxon)
40 Pubescence harsh, at least some of the stiff hairs strongly spreading and pustulate at the base; fruit of 4 nutlets, some of them occasionally abortive ..... BORAGINACEAE
40 Pubescence not especially harsh, the hairs not pustulate at the base
41 Hairs pick-shaped (short stalked at about the middle, the stalk acting as a pivot on which one end of the appressed hair can be turned and the opposite end will turn about equal distance—a feature not easily detected without a dissecting scope and teasing needle) (*Erysimum*) ..... BRASSICACEAE
41 Hairs not pick-shaped, sometimes scurfy
42 Plants with appressed hairs; fruit a capsule; petals 4, conspicuous ..... ONAGRACEAE
42 Plants scurfy, pilose, or sericeous to tomentose; fruit an urticle; petals lacking ..... CHENOPODIACEAE

SECTION II: FAMILIES, GENERA, SPECIES

AGAVACEAE; AGAVE FAMILY

***Yucca* L. Yucca; Spanish Bayonet**

***Yucca harrimaniae* Trel.** Harriman yucca, hoary yucca. (*Y. gilbertiana* [Trel.] Rydb.) Plants with semiwoody caudices; leaves basal, 10-30 (50) cm long, stiff, thick, linear, entire, glaucous, the tips spinose, the margins with exfoliating curly fibers; scapes 10-60 cm tall; flowers racemose, 4-6 cm long, pendant, the tepals white to pale green or cream; fruit a dehiscent capsule. Infrequent, hills and washes. Late May through June. *Yucca baccata* Torr. is cultivated at Headquarters. This differs from *Y. harrimaniae* by leaves to 65 cm long and to 5 cm wide and with indehiscent fruits.

AMARANTHACEAE; AMARANTH FAMILY

***Amaranthus* L. Amaranth; Pigweed**

Annual, weedy herbs; leaves alternate, petioled, entire to wavy margined; flowers inconspicuous, clustered in leaf axils or crowded in terminal or axillary simple or compound spikes, the staminate ones mixed with the pistillate ones, subtended by green or red to purple bracts; sepals 1-5, free, membranous or herbaceous; petals lacking; stamens (1-3) 5; ovary superior, the styles 1-3; fruit a membranous, 1-seeded, circumscissile capsule; seeds shiny, blackish or dark brown.

1 Flowers in terminal as well as axillary, simple to compound spikes; stems erect; leaves sometimes over 3 cm long ..... *A. retroflexus*
1 Flowers mostly in small axillary clusters; stems prostrate to ascending; leaves 0.8-3 cm long ..... *A. blitoides*

***Amaranthus blitoides* Wats.** Prostrate pigweed. (*A. graecizans* L. misapplied) More or less weedy along roads and about Headquarters. July through October.

***Amaranthus retroflexus* L.** Redroot pigweed. (*A. hybridus* L.) Found in a few years about Headquarters (CCC Camp).

ANACARDIACEAE; SUMAC FAMILY

***Rhus* L. Sumac**

***Rhus trilobata* Nutt. var. *simplicifolia* (Greene) Barkl.** Skunkbush sumac, squawbush. Shrubs 70-150 cm tall; leaves alternate, simple but deeply 3-lobed and usually coarsely toothed; flowers appearing before the leaves, small but in conspicuous clusters; petals 2-3 mm long, yellow-green; fruit 6-8 mm long; subglobose, red. Infrequent along Mountain Home Wash through Red Hills.

APIACEAE (UMBELLIFERAE); PARSLEY FAMILY

Perennial herbs (ours); leaves basal in ours, once to many times compound; flowers in umbels; umbels sometimes subtended by an involucre of bracts; pedicels sometimes subtended by an involucel of bractlets; calyx minute or lacking; petals small; fruit a schizocarp sometimes splitting at maturity into 1-seeded mericarps and disclosing a wire-like carpophore to which the reflexed mericarps are basally attached.

1 Leaves finely dissected into numerous ultimate small leaflets, the leaflets not over 3 mm wide
  2 Rays of the umbel enveloped in a scarious involucre; flowers white or purplish; fruit with wings on the back as well as the lateral margins; plants developing a pseudoscape; carpophore mostly lacking ..... *Cymopterus*
  2 Involucre lacking; flowers yellowish; fruit with lateral wings only; pseudoscape lacking ..... *Lomatium*
1 Leaflets 3, 5-20 (30) mm wide, or leaves simple and ternately cleft ..... *Cymopterus*

Cymopterus Raf. Springparsley

Scapose perennial herbs from fibrous often enlarged taproots; leaves 3-foliate to pinnately compound; umbels solitary; carpophore lacking or rudimentary; fruit strongly flattened, dorsal and lateral ribs winged.

1 Leaves finely dissected into numerous segments; rays of the umbel enveloped in a scarious involucre; flowers enveloped by scarious involucels, whitish or purplish; umbel headlike in fruit ..... *C. purpurascens*
1 Leaves at most 3-foliate, the leaflets 5-20 (30) mm wide, involucres and involucels lacking or green and not enveloping the rays or flowers; umbel not headlike
  2 Flowers yellow; involucels green, well developed; leaves trifoliate, usually with a conspicous rachis; plants restricted to sandy ground in Pine Valley ..... *C. newberryi*
  2 Flowers white or purplish; involucels lacking or scarious; leaves simple or trifoliate without a rachis; plants of upper fans and hills ..... *C. basalticus*

***Cymopterus basalticus* Jones** Dolomite springparsley, funnel flower, or funnel leaf. (*Aulospermum basalticum* [Jones] Tidestrom) Endemic to west Millard and Beaver Counties, UT, and adjacent White Pine County, NV; occasional on shallow soils over bedrock and on older alluvial fans. April through June. The name "*basalticus*" is a misnomer because the plant is found on dolomite and not on basalt.

***Cymopterus newberryi* (Wats.) Jones** Sweetroot springparsley. Known from sandy ground at the east edge of the DER just north of Pine Valley Hardpan. April through June.

***Cymopterus purpurascens* (Gray) Jones** Purple springparsley. (*C. utahensis* Jones; *Phellopterus utahensis* [Jones] Woot. & Standl.) Infrequent, mostly in hills and on fans. Late February through April.

Lomatium Raf. Biscuitroot; Desertparsley

Perennial scapose herbs from thickened taproots or caudices; leaves compound, much dissected into fine ultimate segments; umbels solitary; flowers small, yellowish; fruit flattened, the dorsal ribs more or less prominent, the lateral ribs winged.

1 Plants densely hirtellous ..... *L. foeniculaceum*
1 Plants glabrous
  2 Plants strongly aromatic; leaves ovate in outline; primary leaflets borne on petiolules 1 cm long or longer; ultimate segments 0.2-0.3 mm wide, more than 150 per leaf ..... *L. grayi*
  2 Plants weakly if at all aromatic; leaves oblong, the primary leaflets sessile or nearly so; ultimate segments 0.4-2 mm wide, about 50-110 per leaf ..... *L. scabrum*

***Lomatium foeniculaceum* (Nutt.) Coult. & Rose var. *macdougalii* (Coult. & Rose) Cronq.** Fennel-leafed desertparsley. (*Cogswellia jonesii* [Coult. & Rose] Jones; *C. macdougalii* [Coult. & Rose] Jones; *L. macdougalii* Coult. & Rose) Infrequent; mostly in hills. April through May.

***Lomatium grayi* Coult. & Rose** Desertparsley. (*Cogswellia grayi* Coult. & Rose) Occasional to common or locally abundant in cracks of rocks, outcrops, and rocky ground in hills. Late April to mid-June.

***Lomatium scabrum* (Coult. & Rose) Mathias** Rough lomatium. (*Cynomarathoum scabrum* Coult. & Rose) Occasional or common or locally abundant, rock crevices and rocky ground, in hills. Late April to mid-June.

ASTERACEAE (COMPOSITAE); SUNFLOWER OR THISTLE FAMILY

Plants annual, biennial, or perennial, herbs or shrubs (ours); leaves basal, alternate, or opposite; flowers borne in heads subtended by an involucre of separate or united bracts; calyx modified to a pappus or none, the pappus of awns, scales, or of capillary or plumose bristles; corollas of 2 types, one type (disc corollas) tubular, regular, and mostly 5-lobed, the other type (ray corollas or rays) flattened and strap-shaped and 2-5 toothed at the apex; stamens usually 5, inserted on the corolla, usually united by their anthers or sometimes by their filaments; ovary inferior, 1-celled, 1-ovuled; styles usually 2-branched; fruit an achene, the achene often bearing the pappus.

1 Plants shrubs, woody well above ground level
  2 At least some of the leaves lobed or dissected, aromatic with sagebrushlike (camphorlike) odor, densely gray pubescent on both sides or else pinnately divided . . . . . *Artemisia*
  2 Leaves entire or slightly toothed, not with sagebrushlike odor, not pubescent as above
    3 Leaf blades ovate or broader, abruptly constricted to a distinct petiole, sometimes toothed, sometimes opposite, 3-14 mm long; plants woody only at the base . . . . . *Perityle*
    3 Leaf blades narrower than ovate, mostly linear to oblanceolate or nearly so, sessile or gradually narrowed to a petiolelike base, entire, alternate
      4 Involucral bracts 10-15 mm long, with alternating greenish and whitish parallel longitudinal lines (striate); flowers greenish, white, or cream when fresh, drying brownish-red; plants glandular-pubescent, strongly aromatic, flowering in spring . . . . . *Brickellia*
      4 Involucral bracts less than 10 mm long, not striate; flowers yellow; plants glandular or not, aromatic or not, flowering in summer and fall except in *Tetradymia*
        5 Pappus of scales; heads with 3-7 ray flowers; twigs of the current year glabrous or at most scabrous, at least the upper two-thirds green throughout the growing season . . . . . *Gutierrezia*
        5 Pappus of capillary bristles; ray flowers lacking except in *Haplopappus*; twigs of the current year pubescent, or if glabrous then usually whitish (at least not green) before flowering time
          6 Involucral bracts only 4-6 per head, about equal in 1 series, not imbricate, 5-10 mm long; twigs sometimes spiny, those of the season woolly-tomentose, the tomentum not impregnated with resin; leaves glabrous, nearly terete . . . . . *Tetradymia*
          6 Involucral bracts mostly more than 6, slightly to strongly imbricate, at least the outer ones less than 5 mm long; twigs not spiny, tomentose or not, the tomentum when present often impregnated with resin; leaves glabrous or pubescent
            7 Young stems longitudinally striate with alternating lines of tomentum and glabrous or glabrate-glutinous ridges that are slightly raised above the tomentum; involucral bracts rather broad with rounded tips; plants localized in a sandy-gravelly wash in Pine Valley just to the east of the DER (scaleybroom) . . . . *Lepidospartum latisquamum* Wats.
            7 Young stems glabrous to tomentose but not striate as above; involucral bracts mostly narrow with acute to acuminate tips
              8 Ray flowers 1-10; disc flowers 4-15; involucres 3-8 mm wide, the bracts not or only weakly aligned in vertical rows; leaves oblanceolate to narrowly oblanceolate, many of them abruptly tipped with a mucro, sometimes stipitate-glandular; greenish twigs more or less stipitate-glandular or internodes only 1-3 mm long; plants of rock crevices and other rocky places in hills . . . . . *Haplopappus*
              8 Ray flowers lacking; disc flowers various; involucres mostly 2-4 mm wide, the bracts more or less aligned in vertical rows; leaves linear to narrowly oblanceolate, mostly gradually tapered to the tip, not stipitate glandular; twigs often grayish or white, or if green then with tomentum matted in resin, glandular, the internodes usually over 3 mm long; plants of various habitats . . . . . *Chrysothamnus*

1 Plants herbaceous, sometimes with a woody caudex, but this not extending much above ground level
9 Leaves all basal
10 Leaves pinnatifid to pinnately compound; heads with either all ray flowers or all disc flowers
11 Heads with ray flowers only; plants with milky juice, not tomentose; scapes hollow; introduced and probably restricted to irrigated places and Headquarters (dandelion) (*Leontodon taraxacum* L.) . *Taraxacum officinale* Weber in Wiggers
11 Heads with disc flowers only; plants not with milky juice, tomentose, scapes not hollow; indigenous . . . . . *Hymenopappus*
10 Leaves entire; heads with ray and disc flowers
12 Leaves 6-15 cm long including the petioles, the blades 1.5-3.5 cm wide; herbage densely white-pubescent . . . . . *Enceliopsis*
12 Leaves shorter or narrower than above, or both
13 Marginal (ray) flowers white or pink, only the center of the heads (disc corollas) yellow; plants pubescent but not woolly . . . . . *Erigeron*
13 Ray and disc corollas yellow; plants glabrous to woolly at the base
14 Plants glabrous or at most scabrous; pappus of capillary bristles . . . . . *Haplopappus*
14 Plants densely woolly toward the base just above the root crown, sometimes pubescent above; pappus of hyaline scales . . . . . *Hymenoxys acaulis*
9 Leaves not all basal
15 Leaves compound or deeply lobed to pinnatifid (at least some), not with spiny margins, the basal cut ones sometimes deciduous leaving entire or nearly entire stem-leaves, but then plants with milky juice
16 Hairs of stems strongly spreading, more or less stiff, multicellular, pustullate at the base; heads unisexual, the pistillate involucres burlike with 2-4 mm long prickles; flowers inconspicuous, pappus lacking; plants annual, flowering in late August through September . . . . . *Ambrosia*
16 Plants glabrous or with soft more or less tomentose hairs; involucres not burlike; plants annual and with conspicuous flowers in spring and summer or perennial; pappus present or plants perennial
17 Plants not with milky juice, usually more or less tomentose at least when young; heads with disc flowers, rays sometimes lacking; pappus lacking, or of scales, or of capillary bristles only in *Senecio*
18 Plants with sagebrushlike odor, perennial, flowering July through August (occasional plants of the woody *Artemisia spinescens* with flowers in spring may key here); flowers rather inconspicuous; involucres about 3-5 mm high; pappus lacking . . . . . *Artemisia*
18 Plants without sagebrushlike odor, annual or perennial, flowering in spring and early summer; flowers conspicuous; involucres 5-17 mm high; pappus of scales or bristles
19 Ray flowers 3-8 mm long (or longer), yellow; pappus of capillary bristles; primary lobes of leaves mostly not entire, not linear, some usually over 3 mm wide . . . . . *Senecio*
19 Ray flowers lacking except in *Hymenoxys* which has leaves with linear lobes; pappus of scales; primary lobes of leaves often entire or linear or both, at least narrow, not over 3 mm wide
20 Ray flowers 9-14, 8-20 mm long, yellow; disc flowers yellow; leaves once pinnatifid with 3-7 linear entire segments about 1-3 cm long, or a few leaves entire . . . . . *Hymenoxys*
20 Ray flowers lacking; leaves mostly twice or more pinnatifid
21 Corollas yellow; plants long-lived perennials from branched caudices; leaves mostly basal, those of the stem mostly bractlike and mostly entire . . . . . *Hymenopappus*
21 Corollas white, cream, or pinkish; plants annual or biennial from taproots; leaves of mid-stem usually well developed and about equally cut as the lower leaves; basal leaves lacking or in a rosette the first season . . . . . *Chaenactis*
17 Plants with milky juice, glabrous or glabrate; heads with ray flowers only; pappus of capillary or capillary-plumose bristles

22 Ray corollas yellow, 7-14 mm long; pappus of simple bristles; leaves persisting at flowering time ..... *Malacothrix*
22 Ray corollas pinkish, 4-7 mm long; pappus various; leaves often deciduous by flowering time
23 Pappus bristles simple; plants 5-20 cm tall (DER) ..... *Prenanthella*
23 Pappus bristles plumose; plants often over 20 cm tall ..... *Stephanomeria*
15 Leaves entire or toothed, or if lobed then with spiny margins; plants not with milky juice
24 Leaf blades lance-ovate or broader, obtuse, truncate or cordate at the base and rather abruptly constricted to a distinct petiole, sometimes toothed, sometimes opposite
25 Leaf blades 3-14 mm long; ray flowers lacking; disc corollas yellow; plants 10-20 (30) cm tall, perennial, of rocky places in hills ..... *Perityle*
25 Leaf blades over 20 mm long; rays 15-40 mm long, yellow; disc corollas brownish or blackish; plants (25) 30-60 cm tall or taller, annual, usually along roads and other disturbed places ..... *Helianthus*
24 Leaf blades narrower than above, mostly linear, narrowly elliptic, or narrowly oblanceolate, sessile or gradually tapered to a petiolelike base, toothed or entire, never opposite
26 Leaves sharply toothed to spinulose or spiny on the margins, sometimes auriculate clasping at the base; plants not from rhizomes
27 Plants resinous throughout, not hairy; pappus of deciduous short awns; ray and disc corollas yellow; leaves toothed the entire length, not spinulose; involucral bracts strongly recurved ..... *Grindelia*
27 Plants not resinous, except sometimes in the involucre, short-hairy to woolly; ray flowers lacking or not yellow; disc flowers various; leaves more or less spinulose; involucral bracts various
28 Corollas pinkish or whitish; heads with disc flowers only, involucral bracts spinose; plants with some tomentose or floccose hairs, mostly 60-150 cm tall ..... *Cirsium*
28 Disc corollas yellow, ray flowers if present with whitish to purple corollas; involucral bracts not spinose; plants not all tomentose or floccose, mostly 5-40 cm tall ..... *Machaeranthera*
26 Leaves entire, or if a few with lobes or teeth then plants rhizomatous
29 Plants 20-55 cm tall, from rhizomes, densely tomentose; leaves commonly entire but at least some usually toothed to deeply lobed . *Artemisia ludoviciana*
29 Plants mostly less then 20 cm tall, from rhizomes only in *Aster chilensis* (see lead 33 below), not densely tomentose; leaves entire
30 Ray and disc flowers yellow, sometimes small and rather inconspicuous; plants woody at the base, glabrous or at most scabrous, often viscid
31 Rays 6-15, 8-12 mm long; involucres 8-20 mm wide; plants flowering in May through June ..... *Haplopappus*
31 Rays (0) 1-4 (7), 2-7 (9) mm long; involucres 1.5-3.5 mm wide; plants flowering in August through October
32 Pappus of capillary bristles; leaves in a basal tuft, reduced in size and number upward on the stems, 1-11 mm wide ..... *Petradoria*
32 Pappus of hyaline scales; leaves not in a basal tuft, not much if any reduced in size or number upward on the stem, 1-3 mm wide ..... *Gutierrezia*
30 Rays white, pinkish, or lavender; plants mostly not woody at the base, mostly pubescent, not or rarely viscid
33 Plants rhizomatous, probably restricted to irrigated places at Headquarters; rays whitish to bluish (everywhere aster) . *Aster chilensis* Nees
33 Plants not rhizomatous, not restricted as above
34 Involucral bracts mostly in a single series (except in *Erigeron argentatus*), mostly the same color throughout, not scarious margined and ciliate-fimbriate; ray flowers mostly over 20 per head; plants perennial from taproots and sometimes caudices; some leaves usually over 2 cm long ..... *Erigeron*
34 Involucral bracts in 2 or more overlapping series, sometimes bicolored, scarious margined and ciliate-fimbriate; ray flowers

mostly less than 20 per head; plants annual or biennial, or if perennial then the leaves not over 2 cm long

35 Involucres 5-6 mm high; ray flowers exceeding the involucres by 1-3 mm, white; leaves 2-12 (20) mm long, linear or nearly so, a basal tuft lacking; plants perennial from branched caudices ..... *Leucelene*

35 Involucres 7-8 mm high; ray flowers exceeding the involucre by 6-10 mm, usually pinkish; leaves 10-30 mm long, narrowly oblanceolate to linear, 3-12 mm wide, a basal rosette often well developed; plants annual or biennial from taproots (odd specimens or basal rosettes of *Machaeranthera canescens* might be keyed here) ..... *Townsendia*

Ambrosia L. Ragweed

***Ambrosia acanthicarpa* Hook.** Bur ragweed. (*Franseria acanthicarpa* [Hook.] Coville) Annual, 9-50 (75) cm tall, pubescent with stiff pustulate hairs; leaves alternate or a few lower ones opposite, 1-4.5 cm long, pinnatifid to bipinnatifid; heads unisexual, the staminate ones in terminal racemes, nodding, consisting of stamens enveloped in a cuplike involucre; pistillate flowers in axils of leaves, the involucres burlike with prickles 2-4 mm long; corollas lacking; pappus lacking. Occasional in gravelly washes and in sandy areas, usually on disturbances.

Artemisia L. Sagebrush; Wormwood; Mugwort

Perennial herbs or shrubs, mostly aromatic; leaves alternate, entire, lobed or dissected; heads small, mostly in panicles, or spicate panicles; involucral bracts imbricate in 2-4 series; ray flowers obsolete or lacking; disc flowers few; pappus none.

1 Plants rhizomatous herbs; leaves mostly 3-5 lobed at apex ..... *A. ludoviciana*

1 Plants shrubs, not rhizomatous; leaves various

2 Leaves dissected with 5 or more linear or narrow segments; plants mostly 5-30 cm tall

3 Old flowering stalks developing into spines 10-30 mm long; leaves palmately dissected; plants flowering late May to early June; corollas and achenes densely long-hairy ..... *A. spinescens*

3 Old flowering stalks not spiny; leaves more or less pinnately dissected; plants flowering August through October; corollas and achenes glabrous or glandular

4 Leaves distinctly once pinnate, green and nearly glabrous, 2-8 mm long; plants 5-20 cm tall ..... *A. pygmaea*

4 Leaves more than once pinnate; silvery-canescent, 6-12 mm long; plants 5-40 cm tall ..... *A. frigida*

2 Leaves entire, lobed or toothed, the lobes or teeth generally 2-5 per leaf

5 Heads with 1-3 fertile flowers, the involucral bracts villous throughout; leaves entire or finely tridentate with some of the teeth or lobes rather acute; flowering stalks often over a third the height of the plant ..... A. *bigelovii*

5 Heads with 3-8 fertile flowers, the involucral bracts often glabrate in part; leaves mostly with 3 (5) rounded lobes or teeth; flowering stalks often less than a third the height of the plant

6 Plants mostly 5-30 cm tall, common and widespread on the DER; leaves mostly with dark green glandular dots showing through the pubescence .. *A. nova*

6 Plants 60-150 cm tall, restricted to a few places along Mountain Home Wash; leaves without or with obscure glandular dots showing through the pubescence ..... *A. tridentata*

***Artemisia bigelovii* Gray** Bigelow sagebrush. Occasional in rocky places in hills. August through September.

***Artemisia frigida* Willd.** Fringed sagebrush. Locally common in a few places, seems to grow in eroding washes in Antelope Valley, but in loamy flats in Pine Valley. August through October. Grazed by sheep in winter and early spring.

***Artemisia ludoviciana* Nutt.** Louisiana sagebrush, western mugwort, prairie sage. (*A. gnaphalodes* Nutt.; *A. incompta* Nutt.) Infrequent or rare in gravelly washes and rocky canyon bottoms of hills. July through September. DER plants are referable to var. *ludoviciana*.

***Artemisia nova* A. Nels.** Black sagebrush. (*A. arbuscula* Nutt. ssp. *nova* [A. Nels.] Ward; *A. tridentata* ssp. *nova* H. & C.) Common to dominant on hills and sometimes valleys where soil is shallow over bedrock (Paleozoic sedimentary or Tertiary volcanic) or over strongly developed calcic horizons. Undoubtedly more common prior to grazing, and increasing where rested in at least some winters. August through September. Evergreen, prized sheep feed,

consistently palatable all winter long, and the staple of antelope winter diet on the DER.

***Artemisia pygmaea* Gray** Pygmy sagebrush. Abundant in few local areas. August through September.

***Artemisia spinescens* D.C. Eaton in Wats.** Bud sagebrush. Rare to common over most alluvial fan areas, probably much more abundant formerly than now, increasing in ungrazed areas and where sheep graze only in the cold part of winter. May to early June, with leaves and fruits deciduous before July. Highly palatable to sheep (less so to cattle), especially in late winter and early spring.

Artemisia tridentata* Nutt. ssp. *tridentata Basin big sagebrush. Known only from the canyon of Mountain Home Wash through Halfway Hills.

Brickellia Ell. Brickellbush

***Brickellia oblongifolia* Nutt.** Mohave brickellbush. (*Coleosanthus oblongifolius* [Nutt.] Kuntze) Subshrubs or herbs, strongly aromatic, 10-30 (50) cm tall; leaves alternate, sessile or nearly so, 1-4 cm long, 1-15 mm wide, entire, glandular; involucral bracts 10-15 mm long, strongly striate; ray flowers lacking; disc flowers greenish, pappus of capillary bristles. Infrequent to common in washes across the fans that skirt Tunnel Springs Mountain. May through July.

Chaenactis DC. Chaenactis; Dusty Maiden; False Yarrow

Annual, biennial, or perennial herbs; leaves alternate or mainly basal, pinnately dissected or entire; heads solitary to several; involucral bracts in 1-3 series; ray flowers lacking; disc flowers whitish or pinkish; pappus of 4-20 hyaline scales.

1 Plants biennial or short-lived perennial with a well-developed basal rosette of leaves, rare on the DER; pappus of 10-16 scales ..... *C. douglasii*
1 Plants annual, lacking a well-developed basal rosette of leaves, infrequent or common in some years; pappus of 4-8 scales
  2 Heads 15-22 mm high; flowers pink, longer than the involucre; anthers included; pappus scales in 2 sets (4 inner longer ones and 2-4 outer shorter ones) .. *C. macrantha*
  2 Heads 6-11 mm high; flowers white, about equal or slightly longer than the involucre; anthers exserted; pappus scales in 1 set of 4 ..... *C. stevioides*

***Chaenactis douglasii* (Hook.) H. & A.** Douglas or hoary chaenactis. The one specimen seen is from near Halfway Summit. May through June.

***Chaenactis macrantha* D.C. Eaton** Bighead chaenactis. Occasional or locally common at least in some years, mostly in areas of rodent activity on upper fans. May through June.

***Chaenactis stevioides* H. & A.** Dryland false yarrow. Locally abundant in a few years following heavy autumn or winter moisture, not seen in some years; mostly in valleys. May through June.

Chrysothamnus Nutt. Rabbitbrush

Low to tall shrubs, commonly resinous and aromatic; leaves alternate, sessile or nearly so, linear to filiform, entire; inflorescence usually a racemose panicle or cyme; heads small, the involucres cylindrical, the bracts imbricate in more or less distinct vertical rows; ray flowers none; disc flowers 4-7 per head, yellow; pappus of capillary bristles.

1 Young stems tomentose, the tomentum often matted in and obscured by a thick coat of resin; plants 30-130 cm tall ..... *C. nauseosus*
1 Young stems glabrous or at most scabrous; plants 15-40 cm tall, rarely taller
  2 Involucral bracts acuminate-cuspidate; leaves 1-2 mm wide ..... *C. greenei*
  2 Involucral bracts obtuse or acute; leaves 1-5 mm wide ..... *C. viscidiflorus*

***Chrysothamnus greenei* (Gray) Greene** Greenes low rabbitbrush. Abundant to dominant on sandy fans.

***Chrysothamnus nauseosus* (Pallas) Britt.** Rubber rabbitbrush. With 3 ssp. on the DER.

1 Involucres 9-11 mm high; corollas lobes villous; achenes glabrous or pubescent; plants of eolian sand in Pine Valley east of the DER (sanddune rubber rabbitbrush) ..... ssp. *turbinatus* (Jones) H. & C.
1 Involucres less than 9 mm high; corolla lobes not villous; achenes various; plants found on the DER
  2 Ovaries and achenes glabrous; young stems greenish; leaves about 1-3 cm long, 0.5-1 mm wide, often deciduous before flowering time, terete or loosely triangular in cross section with a longitudinal groove on the upper side, keeled or rounded but not grooved on the lower side except sometimes at the base, with midnerves lacking or obscure; tomentum of leaves about equally matted in resin as that of the stems, or some hairs (especially those along the groove) free of the resin ..... ssp. *leiospermus*

2 Ovaries and achenes hairy; young stems greenish or grayish; leaves sometimes over 3 cm long, sometimes over 1 mm wide, persistent at flowering time, flattened to strongly folded to nearly terete in cross section, variously grooved or not, with conspicuous midnerves; tomentum of leaves sometimes not matted in resin
  3 Involucral bracts glabrous or ciliate with translucent hairs of the same texture as the scarious margins of the bract; young stems yellow-green; leaves less than 1 mm wide, loosely to strongly folded to nearly terete, grooved above, the lower midrib grooved; plants known from Headquarters (threadleaf rubber rabbitbrush) ..... ssp. *consimilis* (Greene) H. & C.
  3 Involucral bracts (especially the lower ones) more or less tomentose, the hairs not all of the same texture as the scarious margin of the bracts; young stems gray or gray-green; leaves about 0.7-3 mm wide, flat to loosely folded, not grooved above, the lower midrib often keeled and not or obscurely grooved; plants widespread ..... ssp. *hololeucus*

Ssp. *hololeucus* (Gray) H. & C. All white rubber rabbitbrush. (*C. n.* var. *hololeucus* [Gray] Hall; *C. n.* var. *gnaphalodes* [Greene] Hall; *C. n.* ssp. *gnaphalodes* [Greene] H. & C.) Infrequent or locally common in the gravelly bottoms of some of the major washes and along roadsides and near some structures at Headquarters. September through October. Plants at the DER have grayish, not pure white, stems with the tomentum matted in resin and not loose, and in a strict sense they are referable to ssp. *gnaphalodes*.

Ssp. *leiospermus* (Gray) H. & C. Shortleaf rubber rabbitbrush. (*C. n.* var. *abbreviata* [Jones] Blake; *C. leiospermus* [Gray] Greene; *C. n.* var. *leiospermus* [Gray] Hall) Common to abundant (the most common rubber rabbitbrush on the DER) in gravelly washes, rarely on gravelly hills. August through September.

***Chrysothamnus viscidiflorus* (Hook.) Nutt.** Low rabbitbrush. With three subspecies on the DER.

1 Stems and leaves puberulent ..... ssp. *puberulus*
1 Stems and leaves glabrous or at most scabrous, or leaves ciliate
  2 Leaves about 1 mm wide; involucres somewhat turbinate, with 3-4 (5) flowers ..... ssp. *axillaris*
  2 Leaves 1-5 mm wide, if only 1 mm then involucres narrowly cylindric, with 4 or more flowers ..... ssp. *viscidiflorus*

Ssp. *axillaris* (Keck) L. C. Anderson Narrowleaf rabbitbrush. (*C. v.* ssp. *stenophyllus* H. & C. misapplied [plants from the type locality identical to those of ssp. *viscidiflorus*]; *C. v.* var. *stenophyllus* [Gray] Hall misapplied). Occasional in valleys and on fans.

Ssp. *puberulus* (D.C. Eaton) H. & C. Hairy low rabbitbrush. (*C. puberulus* [D.C. Eaton] Greene; *C. v.* var. *puberulus* [D.C. Eaton] Jeps.). Occasional on hills and fans.

Ssp. *viscidiflorus* Stickleaf low rabbitbrush. (*C. pumilus* Nutt.; *C. v.* ssp. *pumilus* H. & C.; *C. v.* var. *pumilus* [Nutt.] Jeps.; *C. stenophyllus* [Gray] Greene; *C. v.* ssp. *stenophyllus* H. & C.; *C. v.* var. *stenophyllus* [Gray] Hall) Occasional or locally common, restricted to sandy soil in Pine Valley near the east boundary of the DER. August through October.

Cirsium Mill Thistle

***Cirsium neomexicanum* Gray** Lavender thistle. Biennial, spiny herbs from taproots, 60-150 cm tall; leaves 2-35 cm long, the lower much longer than the upper ones, alternate, pinnately lobed or divided, white tomentose at least below, the margins spiny; heads 20-30 mm high, the bracts spine-tipped; ray flowers lacking; disc flowers creamy-white; pappus of plumose bristles. Infrequent or locally common, mostly in hills. June through July.

Enceliopsis (Gray) A. Nels.

***Enceliopsis nudicaulis* (Gray) A. Nels.** Barestem enceliopsis. Perennial herbs, 10-43 cm tall; herbage silvery-white with dense pubescence; leaves all basal, the petioles 7-17 cm long, the blades 2-9 cm long, entire, heads solitary on a naked or bracteate scape; involucres 13-22 mm high; ray flowers yellow, 22-38 mm long; disc flowers yellow; pappus usually of 2 awns. Occasional to common on rocky outcrops and gravelly or rocky ground in hills. May through June.

Erigeron L. Fleabane; Daisy

Perennial herbs; leaves alternate or nearly all basal, entire, mostly linear to oblanceolate, heads mostly solitary or few; ray flowers usually well developed, white, pink, blue, or lavender; disc flowers yellow; pappus of capillary bristles.

1 Leaves all or nearly all basal, 4-20 mm long, 0.5-1.5 mm wide; plants pulvinate caespitose, 2-7 (10) cm tall ..... *E. compactus*
1 Leaves not all basal, some usually over 20 mm long or over 1.5 mm wide or both; plants sometimes caespitose but hardly pulvinate, of various stature
2 Hairs widely spreading (about 60°-90°) from the stem; plants common and widespread ..... *E. pumilus*
2 Stems with appressed hairs or glandular-scabrous; plants known from Tunnel Springs Mountain
3 Herbage glandular-scabrous, sometimes sparingly strigose also, greenish, more or less malodorous ..... *E. nauseosus*
3 Herbage densely pubescent, grayish or whitish
4 Involucres 3.5-5 mm high, the bracts in a single series, glandular, with spreading hairs; ray flowers 4-8 mm long, 1-1.7 mm wide; plants 3-10 (15) cm tall, found mostly above 8,000 ft ..... *E. tener*
4 Involucres 5.5-9 mm high, the bracts imbricate in 2-3 series, not glandular, with appressed hairs; ray flowers 9-15 mm long, 1.5-2.8 mm wide; plants 9-30 cm tall, mostly below 8,000 ft ..... *E. argentatus*

***Erigeron argentatus* Gray** Silver daisy. Infrequent to locally common on Tunnel Springs Mountain. May through June.

Erigeron compactus* Blake var. *compactus Pulvinate daisy. Locally common in a few places on the east side of Tunnel Springs Mountain; mahogany-pinyon-juniper communities. May through June.

***Erigeron nauseosus* (Jones) A. Nels.** Marysvale daisy. Rare on quartzite outcrops of Tunnel Springs Mountain. May through June.

***Erigeron pumilus* Nutt. ssp. *concinnoides* Cronq.** Low fleabane, vernal daisy. (*E. concinnus* [H. & A.] T. & G.) The common daisy of the DER, mostly in hills. May through June.

***Erigeron tener* Gray** Slender or thin daisy. Locally occasional to common in a few places at the upper elevations of Tunnel Springs Mountain. May through June.

Grindelia Willd. Gumweed; Resinweed

***Grindelia squarrosa* (Pursh) Dunal var. *serrulata* (Rydb.) Steyermark** Strongly resinous, biennial or short-lived perennial herbs, from taproots, 10-70 cm tall; leaves alternate, entire to toothed; involucres 7-9 mm high, the bracts imbricate, often strongly recurved or reflexed from the base; ray flowers yellow, 7-15 mm long; disc flowers yellow; pappus of 2-3 (6) deciduous awns. Known from along Highway 21 near Halfway Summit, to be expected elsewhere along roads. June through October.

Gutierrezia Lag. Snakeweed

***Gutierrezia sarothrae* (Pursh) Britt. & Rusby** Broom snakeweed. (*Xanthocephalum sarothrae* [Pursh] Shinners) Short-lived perennial forbs or subshrubs, 10-30 cm tall, rarely taller on the DER; leaves alternate, linear, entire, the main ones often with fascicles of secondary leaves in the axils; heads several to many; involucres 3-5 mm high, the bracts imbricate; ray flowers 3-7, yellow, 2-5 mm long; disc flowers yellowish; pappus of 8-10 scales. Common to abundant, widespread, mostly in valleys, but also in hills, especially common along roads and areas disturbed by rodents. July through September, some leaves remain green through much of the winter. The presence and persistence of snakeweed in plant communities at the DER is not related to grazing. Little used by sheep in winter, but important feed for antelope year around.

Haplopappus Cass. Goldenweed

Perennial forbs or shrubs; leaves alternate or nearly all basal, mostly entire; heads mostly solitary or few; the bracts more or less imbricate but not in vertical rows; ray flowers usually well developed, yellow; disc flowers yellow; pappus of numerous capillary bristles.

1 Plants herbaceous above ground level with a woody branching caudex; leaves 3-60 mm long, in a basal tuft and sometimes reduced in size or number upward on the stem; ray flowers 8-12 mm long ..... *H. acaulis*
1 Plants shrubs, woody above ground level; leaves not in a basal tuft, 3-28 mm long, not much if any reduced in size or number upward on the stems; ray flowers 2-6 mm long
2 Leaves densely stipitate-glandular, oblanceolate, acute, the margins not especially wavy; plants of upper parts of Tunnel Springs Mountain; ray flowers 4-6 mm long ..... *H. watsonii*

2 Leaves lacking stipitate glands, narrowly oblanceolate or if oblanceolate then the margins rather wavy; plants of various distribution; ray flowers 2-4 mm long
3 Leaves 2-5 mm wide, oblanceolate, often wavy margined; twigs (not leaves) more or less stipitate-glandular ..... *H. cervinus*
3 Leaves 0.5-2 mm wide, narrowly oblanceolate to oblong, not wavy margined; twigs resinous but not stipitate-glandular ..... *H. nanus*

***Haplopappus acaulis* (Nutt.) Gray var. *glabratus* D.C. Eaton** Stemless goldenweed. (*Aplopappus acaulis* [Nutt.] Blake) One of the most common forbs on hills of the DER, sometimes also on banks of washes. May through June.

***Haplopappus cervinus* Wats.** (*Aplopappus cervinus* Wats.) Occasional in rock crevices and rocky places, the few specimens seen are from Tunnel Springs Mountain. August through October.

***Haplopappus nanus* (Nutt.) D.C. Eaton in Wats.** Dwarf goldenweed. (*Aplopappus nanus* [Nutt.] D.C. Eaton) Occasional to abundant, crevices of rock outcrops and in rocky places in hills. August through October.

***Haplopappus watsonii* Gray** Watson goldenweed. (*Aplopappus watsonii* Gray) Infrequent to occasional in rocky places on Tunnel Springs Mountain. August through October. Some of our specimens are somewhat intermediate to *H. cervinus*.

Helianthus L. Sunflower

***Helianthus annuus* L.** Common sunflower, wild sunflower. Annual herbs, 30-100 cm tall, rarely taller on DER; lower leaves opposite, upper ones alternate, 3-20 (to 40, but doubtfully this long on DER) cm long, the blades more or less ovate; heads 1-few; involucral bracts imbricate; ray flowers yellow, 1.5-3 (4) cm long; disc flowers blackish or dark reddish-purple; pappus of 2 awnlike scales. More or less weedy along roadsides in some years, not common. June through September.

Hymenopappus L'Her. Hymenopappus

***Hymenopappus filifolius* Hook. var. *nanus* (Rydb.) Turner** Fineleaf hymenopappus. Perennial herbs, 10-30 cm tall, from a caudex, the crown with tufts of woolly or tomentose hair; leaves mostly basal, a few alternate, usually twice-pinnatifid into filiform segments, white pubescent; heads solitary to several, the involucral bracts in 1-2 nearly equal series; ray flowers lacking; disc flowers yellow; pappus of 10-20 minute hyaline scales, these sometimes obscured by the long hairs of the achenes. Occasional, hills, gravelly parts of fans, and shallow soils over bedrock. May through June. Used by antelope in spring and early summer.

Hymenoxys Cass. Actinea; Hymenoxys

Caespitose glabrate to densely long-hairy, perennial herbs (ours), with tufts of woolly hair among the leaf bases; leaves basal or alternate; involucral bracts in 2 or 3 series; ray and disc flowers yellow; pappus of 5-8 scales.

1 Leaves all basal, simple, linear or nearly so, entire; heads solitary on simple scapes ..... *H. acaulis*
1 Leaves basal and on stems, pinnately divided into 3-7 linear segments about 1-3 cm long, occasionally a few simple; heads solitary to several ..... *H. richardsonii*

Hymenoxys acaulis* (Pursh) Parker var. *acaulis Stemless hymenoxys. (*Actinea acaulis* Spreng.; *A. depressa* [T. & G.] Kuntze) Common, widespread, hills and washes. April through June.

***Hymenoxys richardsonii* (Hook.) Cockerell** Pinque hymenoxys. (*Actinea richardsonii* [Hook.] Kuntze) Locally common at Halfway Summit and rarely in washes and driveways. July through September.

Leucelene Greene

***Leucelene ericoides* (Torr.) Greene** Heath aster. (*Aster arenosus* Blake; *A. bellus* Blake; *A. hirtifolius* Blake; *A. leucelene* Blake) Perennial herbs, 5-12 cm tall, with tufted stems; leaves 2-12 (20) mm long, 0.6-2 mm wide, linear, entire, hispid, ciliate, reduced upward on the stem; heads solitary, the bracts imbricate in about 3-7 series; ray flowers to 6 mm long, white; disc flowers yellow, whitish in age; pappus of capillary bristles. Widespread, mostly occasional in small patches, hills, valleys, and washes. June through August.

Machaeranthera Nees. Tansyaster

Annual or perennial herbs; leaves alternate, simple, spinulose toothed; heads various; involucral bracts imbricate; ray flowers various; disc flowers yellow; pappus of capillary bristles.

1 Ray flowers 5-12 mm long, white, pink, or lavender; plants annual or biennial or short-lived perennial from a taproot, mostly of valleys ..... *M. canescens*
1 Ray flowers lacking; plants perennial from a branched caudex, mostly of hills ..... *M. grindelioides*

***Machaeranthera canescens* (Pursh) Gray** Hoary aster. (*M. leucanthemifolia* [Greene] Greene; *Aster canescens*; *A. leucanthemifolia* Greene) Occasional to common, widespread in valleys and hills. July through September in years with summer moisture. Plants of the DER are more or less referable to var. *leucanthemifolia* (Greene) Welsh. The basal leaves remain green in winter, or at least in the early part of winter.

***Machaeranthera grindelioides* (Nutt.) Shinners** Discoid machaeranthera. (*Aplopappus nuttallii* T. & G.; *Haplopappus nuttallii* T. & G.) With 2 vars. on the DER.

1 Plants depressed, rarely over 5 cm tall; mostly with only 1 head, common, widespread; leaves mostly clustered at the base of the plant ..... var. *depressa*
1 Plants not depressed, mostly over 5 cm tall, with 1 or more heads, rather rare, on Tunnel Springs Mountain; leaves not clustered at base of plant .. var. *grindelioides*

Var. *depressa* (Maguire) Cronq. & Keck. (*Haplopappus nuttallii* var. *depressa* Maguire) Occasional to locally common, widespread, on semibarren knolls and hills. June through July.

Var. *grindelioides* Rather rare or locally common in rocky places, known from the east side of Tunnel Springs Mountain. July through August.

Malacothrix DC. Desert Dandelion

Annual herbs with milky juice; leaves basal and alternate, mostly pinnatifid; heads solitary to several, the principal involucral bracts in 1-2 series, with several shorter outer ones; ray flowers yellow; disc flowers none; pappus of capillary bristles.

1 Leaves with lateral lobes regularly toothed; involucres usually less than 1 cm long; achenes 2-3 mm long at maturity; pappus bristles all quickly deciduous; herbage glabrous or with few glandular hairs ..... *M. sonchoides*
1 Leaves with lateral lobes irregularly toothed or lobed; involucres usually over 1 cm long; achenes 3-4 mm long at maturity; pappus mostly quickly deciduous, but 1 or more bristles persistent; herbage often with scattered stipitate-glandular hairs ..... *M. torreyi*

***Malacothrix sonchoides* (Nutt.) T. & G.** Infrequent or occasional, a summer annual not seen in every year, mostly in valleys on sandy soil. May through June. See *M. torreyi*.

***Malacothrix torreyi* Gray** Infrequent or occasional, a summer annual not seen in every year, mostly in valleys. May through June. Easily confused with *M. sonchoides* and rather tenuously separated without mature achenes and pappus.

Perityle Benth. Rockdaisy

***Perityle stansburyi* (Gray) Macbr.** Stansbury rockdaisy. (*Laphamia stansburyi* Gray) Perennial subshrubs, 7-30 cm tall; stems usually several; leaves mostly alternate, but a few sometimes opposite, 3-14 mm long, glandular-hirtellous; heads few to many, the involucres 5-6.5 mm high; the bracts in 1 or 2 subequal series; ray flowers yellow, 4-5 mm long; disc flowers yellow; pappus of 1 stout bristle and a short crown of hyaline scales. Infrequent or occasional, rocky places in hills. June to mid-July.

Petradoria Greene Rock Goldenrod

***Petradoria pumila* (Nutt.) Greene** (*Solidago petradoria* Blake) Plants perennial, tufted, herbaceous above ground level, from woody, branching caudices, 10-20 cm tall, glabrous or scabrous, more or less resinous; leaves simple, alternate, entire, linear oblanceolate, often 3-nerved, reduced in size and number upward on the stem; heads few to several; involucres about 5-6 mm high, the bracts more or less imbricate in vertical rows; ray flowers (0) 1-3, usually inconspicuous, yellow; disc flowers few, yellowish; pappus of capillary bristles. The one specimen (W. P. Cottam, 31) seen is from T25S, R18W and is possibly from the DER.

Prenanthella Rydb.

***Prenanthella exigua* (Gray) Rydb.** (*Lygodesmia exigua* Gray) Annual herbs, 5-15 cm tall, rarely taller, branched; milky juice; leaves alternate; toothed to pinnatifid, withered by flowering time; heads at the ends of branches, the involucres 4-5 mm high, the bracts in 2 series (the outer ones 1-few and much reduced, the inner ones 4-5); ray flowers pink or rose, about 7 mm long; disc flowers none; pappus of capillary bristles. Infrequent or occasional in some years, the few specimens seen are from Warm Cove Ridge. May through June or into July.

Senecio L. Groundsel

***Senecio multilobatus* T. & G. ex Gray** Lobeleaf groundsel. (*S. millelobatus* Rydb.; *S. uintahensis* [A. Nels.] Greenm.) Biennial or short-lived perennial herbs, 10-40 cm tall; leaves alternate, pinnately divided, the segments again variously toothed or lobed; heads few to several, the involucres 4-9 mm high, the bracts in 1 series, sometimes with smaller bracts at base; ray flowers yellow, 4-10 mm long; disc flowers yellow; pappus of numerous capillary bristles. Rare or infrequent along or near Mountain Home Wash. Common in the Mountain Home Range (the apparent seed source for the DER), but probably maturing on the DER only in exceptionally moist years.

Stephanomeria Nutt. Wirelettuce

***Stephanomeria exigua* Nutt.** Annual herbs from slender taproots, 5-40 cm tall, erect, commonly branched; stems often hollow; main leaves 1-6 cm long, pinnatifid, withered and often deciduous by flowering time; leaves of upper parts of stems reduced and bract-like, toothed to entire; involucres 5-10 mm high; ray flowers 3-5, pink or white, 3-5 mm long; pappus-bristles of plumose in the upper half. Rare, not seen in most years. The few specimens seen are from fans and valleys.

***Stephanomeria pauciflora* (Torr.) A. Nels in Coult & Nels.** has been found just south of the DER in Pine Valley. This is a perennial with pappus-bristles plumose to well below the middle.

Tetradymia DC. Horsebrush

Shrubs with stems more or less tomentose at least when young; leaves alternate, solitary or fascicled, entire, narrow, the primary leaves sometimes modified into spines; heads axillary or clustered at the tips of branches; involucral bracts 4-6, in a single row, about equal; ray flowers lacking; disc flowers yellow; pappus of numerous, whitish, capillary bristles.

1 Twigs densely, uniformly, and permanently tomentose, sometimes with recurved spines, these 5-10 (15) mm long; heads solitary or in pairs in the axils of upper leaves; involucral bracts 5-6, tomentose ..... *T. spinosa*
1 At least some of the older twigs tomentose in lines with glabrous lines or glabrate in age; spines if present not recurved; heads (2) 3-many at the ends of twigs; involucral bracts 4 (5)
  2 Twigs armed; spines spreading, rigid, not confined to current year's twigs, 5-25 mm long; involucral bracts tomentose ..... *T. nuttallii*
  2 Twigs unarmed or the leaves of current twigs persisting, appressed or ascending, and weakly spinescent, to 8 mm long; involucral bracts glabrous ... *T. glabrata*

***Tetradymia glabrata* Gray** Littleleaf horsebrush. Dominant on large areas of ancient alluvial surfaces south of Tunnel Springs Mountain, also common on coarse volcanic soils. Late May through June, among the earliest of shrubs to become noticeably green at the end of winter, leaves and fruit usually deciduous by July 1. Used by pronghorn antelope in early spring. Known to be poisonous to sheep.

***Tetradymia nuttallii* T. & G.** Nuttall horsebrush. Dominant on ancient alluvium south of Tunnel Springs Mountain, less frequent than *T. glabrata* (the two species seem to occupy the same sites). Late May through June, growth starts early in spring, leaves and fruit usually deciduous by July 1.

***Tetradymia spinosa* H. & A.** Cottonthorn horsebrush. Widespread but scattered, mostly occurring as lone plants in association with plants of other species, in a number of plant communities on alluvial soils.

Townsendia Hook.

***Townsendia florifer* (Hook.) Gray** Showy townsendia, Townsend aster. Winter annual or biennial herbs, 3-10 (15) cm tall; leaves basal and alternate, 6-50 mm long, entire; heads solitary or few; involucres 6-13 mm high, the bracts in 3 or 4 series; ray flowers white, pink, or lavender, 7-12 mm long; disc flowers yellow; pappus of slightly dilated bristlelike scales. Common but scattered in several plant communities, flowering in most years. May through June.

BORAGINACEAE: BORAGE FAMILY

Annual or perennial herbs, with coarse-pubescent herbage; leaves alternate, entire; flowers with united corolla; fruit of nutlets.

1 Plants perennial or biennial ..... *Cryptantha*
1 Plants annual

2 Plants prostrate-spreading, dichotomously branched, of sandy ground, rare; leaves 4-8 mm long, ovate to nearly suborbicular, with 2-3 distinct pairs of veins on the back; style 2-cleft, stigmas 2 ..... *Tiquilia*

2 Plants ascending or erect, if prostrate then not dichotomously branched; at least some of the leaves over 8 mm long, mostly linear or at least narrower than ovate, not distinctly veined, except for the midrib; style not cleft; stigmas 1

3 Nutlets with prickles ..... *Lappula*

3 Nutlets without prickles ..... *Cryptantha*

Cryptantha Lehm. Cryptantha

In addition to the taxa treated below *C. cinerea* (Greene) Cronq. (*C. jamesii* [Torr.] Payson; *Oreocarya cinerea* Greene) might be found on the DER. This is a perennial with smooth nutlets and whitish corollas.

1 Plants biennial or perennial; corollas comparatively large, the limb 4.5-12 mm wide, the tube 2-13 mm long

2 At least some of the styles exceeding the mature fruit by 4 mm or more, about equal to the calyx through all stages of phenology; corollas white to yellow, the limb 8-12 mm wide, the tube 7-13 mm long, exceeding the calyx; plants about 10-30 cm tall

3 Corollas bright yellow; nutlets smooth; plants about 13-28 cm tall ..... *C. confertiflora*

3 Corollas white or cream-yellow, the tube with an orange or dark yellow crest; nutlets muricate or tuberculate; plants seldom over 16 cm tall ..... *C. flavoculata*

2 Styles equaling or exceeding the mature nutlets by less than 4 mm; shorter than the calyx through all stages of phenology; corollas whitish, the limb 4.5-10 mm wide, the tube 2-4.5 mm long, only equaling the calyx; plants 3-10 (15) cm tall

4 Plants biennial or short-lived perennial, from a simple taproot, without a branched caudex; ventral surface of nutlets smooth or nearly so ..... *C. rugulosa*

4 Plants perennial, from taproots to much-branched caudices; ventral surface of nutlets rugose or variously roughened

5 Plants compact caespitose, 3-10 cm tall; leaves 5-25 mm long; corolla tube 1.8-2.2 mm long; caudex often with blackish epidermis ..... *C. compacta*

5 Plants not or weakly caespitose, 4-15 cm tall; leaves 25 mm long or longer; corolla tube 3-5 mm long; caudex if present usually not with blackish epidermis ..... *C. humilus*

1 Plants annual; corollas small, the limb 1-3 mm wide, the tube mostly not over 3 mm long

6 Plants 2-5 (10) cm tall, usually several stemmed or at least much branched, often forming a dense hemispherical mass; leaves 3-15 mm long; upper half of calyx falling away at maturity; nutlets smooth or nearly so ..... *C. circumscissa*

6 Plants (7) 10-20 cm tall, with solitary or few simple to somewhat branched stems; leaves 10-25 (40) mm long; calyx persistent; nutlets various

7 Nutlets 4, 3 with winged margins and 1 wingless; lower surface of leaves conspicuously pustulate ..... *C. pterocarya*

7 Mature nutlets 1 or rarely 2-3, not winged-margined; leaves mostly inconspicuously pustulate

8 Nutlet smooth and shiny; calyx not bent ..... *C. gracilis*

8 Nutlet roughened; calyx bent ..... *C. recurvata*

***Cryptantha circumscissa* (H. & A.) Johnst.** Matted cryptantha. (*Greeneocharis circumscissa* [H. & A.] Rydb.) Occasionally common, but not seen in most years, mostly in valleys. May through June.

***Cryptantha compacta* Higgins** Compact cryptantha. Occasional in hills. Late April through June.

***Cryptantha confertiflora* (Greene) Payson** Yellow cryptantha. (*Oreocarya confertiflora* Greene) Occasional on fans and hills. May through June.

***Cryptantha flavoculata* (A. Nels.) Payson** Roughseed cryptantha. (*Oreocarya flavoculata* A. Nels.; *O. shockleyi* Eastw.) Occasional to locally common in hills. April through June.

***Cryptantha gracilis* Osterh.** Slender cryptantha. The one specimen seen is from Tunnel Springs Mountain, from duff in shade of pinyon and juniper. May through June.

***Cryptantha humilus* (Gray) Payson var. *commixta* (Macbr.) Higgins** (*Orecarya commixta* Macbr.; *C. nana* [Eastw.] Payson var. *commixta* [Macbr.] Payson) Occasional, valleys and hills. May through June.

***Cryptantha pterocarya* (Torr.) Greene** Winged cryptantha. The few specimens seen are from Tunnel Springs Mountain and Warm Cove Ridge. May through June.

***Cryptantha recurvata* Cov.** Recurved cryptantha. Infrequent or locally common at least in some years, specimens seen are from Antelope Valley and Halfway Hills. May through June.

***Cryptantha rugulosa* (Payson) Payson** The two records seen are from Bullgrass Knoll and Tunnel Springs Mountain. May through June.

Lappula Monch Stickseed

***Lappula redowskii* (Hornem.) Greene** Annual stickseed. (*L. occidentalis* [Wats.] Greene) Annual herbs (5) 10-30 cm tall, more or less canescent with strigose and villous hairs; leaves 1-3 cm long, linear to oblanceolate; corollas white or blue, inconspicuous, the limb 2-4 mm wide; nutlets 3-4 mm long, with rows of slender, hooked bristles along the margins. One of the most common winter annuals across the DER, most common on roadsides and other areas of disturbance. April to early June.

Tiquilia Persoon

***Tiquilia nuttallii* (Hook.) Richardson** Nuttall coldenia. (*Coldenia nuttallii* Hook.) Annual, prostrate, dichotomously branched, finely strigose; leaves constricted to distinct petioles as long or longer than the blades; corollas pink or white, inconspicuous; the limb 2-2.5 mm wide; nutlets smooth and shining. Present, but rare, in occasional years at DER, absent in most years. May through June.

BRASSICACEAE (CRUCIFERAE); MUSTARD FAMILY

Annual or perennial herbs, glabrous or often pubescent with simple, forked or stellate hairs; leaves alternate or basal, simple to compound, the stem leaves sometimes sessile and auriculate; flowers mostly in racemes, bisexual, regular or nearly so, the petals and sepals 4 and separate or petals sometimes lacking, stamens 6; ovary superior; fruit (pods) linear and many times longer than wide (silique) or not linear and only 1-3 times longer than wide (silicle).

1 Key to genera, based largely on features of the mature or nearly mature fruit . KEY 1
1 Key to genera, based primarly on features of the leaves and flowers . . . . . ALTERNATE KEY 1

Key 1

1 Leaves pinnately compound or pinnatifid into fine segments, the segments mostly not over 3 mm wide; petals 1.5-3 mm long or lacking; plants annual or biennial, rarely perennial
  2 Plants stellate-pubescent, mostly 10-40 cm tall, annual; leaves once, twice, or more pinnatifid; petals yellowish; fruit 3-30 mm long . . . . . *Descurainia*
  2 Plants glabrous or with simple hairs, 2-10 (15) cm tall; winter annual, biennial, or rarely short-lived perennial; leaves once pinnately divided; petals whitish; fruit 2.5-4 mm long . . . . . *Lepidium*
1 Leaves not pinnatifid, or if so then the segments over 3 mm wide; petals various but sometimes over 3 mm long; plants various
  3 Fruit not linear, only 1-4 (5) times longer than wide, 2.5-17 mm long; petals white or yellow
    4 Styles 2-8 mm long; plants covered with dense, appressed, many-rayed, stellate hairs; petals 5-13 mm long, yellow; leaves simple, entire, not auriculate clasping; pods more or less inflated; plants perennial
      5 Fruit excluding the style 11-17 mm long at maturity, strongly inflated, obcordate or deeply indented at apex, the styles 4-8 mm long; petals 8-13 mm long; leaves 3-35 mm wide . . . . . *Physaria*
      5 Fruit excluding the style 3-6 mm long, slightly inflated, pointed at the apex; styles 2-4 mm long; petals about 6-8 mm long; leaves 2-6 mm wide . . . . . *Lesquerella*
    4 Styles less than 2 mm long; plants variously pubescent but not as above; petals 2-5 mm long, or obsolete, white to cream; leaves various; pods not or obscurely inflated; plants annual, winter annual, or biennial
      6 Leaves entire or with small teeth

7 Plants 2-5 (10) cm tall, native, pubescent with stalked 2-4 rayed hairs; stem leaves not auriculate ..... *Draba*
7 Plants 10-30 cm tall or taller, introduced, pubescent with simple, forked or stellate hairs; at least the upper leaves auriculate ..... *Camelina*
6 At least some of the leaves pinnately lobed or divided ..... *Lepidium*
3 Fruit linear, over 5 times longer than wide, (10) 15-140 mm long; petals various
8 Petals yellow, 10-28 mm long; plants either pubescent with pick-shaped hairs or pods stipitate
9 At least some of the lower leaves pinnatifid, 5-18 cm long, 2-5 cm wide; stamens exserted, the filaments about twice as long as the petals; pods stipitate, the stipe 1-2.5 cm long; plants 25-80 cm tall or taller, glabrous to pilose with simple hairs, glaucous ..... *Stanleya*
9 Leaves entire, 2-5 (10) cm long, 0.2-1.4 cm wide; stamens included; pods sessile; plants mostly 10-30 cm tall, rarely taller; pubescent with pick-shaped hairs ..... *Erysimum*
8 Petals white, pink or purplish but not yellow, mostly less than 10 mm long; plants glabrous or variously pubescent but not with pick-shaped hairs; pods not stipitate
10 At least some of the leaves pinnatifid, not auriculate; stems either inflated or strongly pilose; pods 7-14 cm long ..... *Caulanthus*
10 Leaves not pinnatifid, those of the stem auriculate or not; stems not inflated, not pilose; pods (1) 2-8.5 cm long
11 Leaves dentate-toothed toward the apex, entire toward the base, obovate to lanceolate, those of the stem strongly auriculate; plants glabrous; pods 5-8.5 cm long, 3-5 mm wide ..... *Streptanthus*
11 Leaves not dentate-toothed toward the apex, usually narrower than above, if auriculate then plants pubescent with forked branched or stellate hairs; pods (1) 2-6.5 cm long, less than 3 mm wide
12 Plants glabrous, annual; pods reflexed-descending ..... *Streptanthella*
12 Plants pubescent with forked, branched, or stellate hairs, perennial or annual; pods descending to erect
13 Pedicels of fruit 1-2 mm long; plants annual, introduced, weedy ..... *Malcolmia*
13 Pedicels of fruit 3-20 mm long; plants perennial, native, not weedy ..... *Arabis*

Alternate Key 1

1 Plants glabrous or with simple hairs only
2 Leaves all entire, not auriculate at the base ..... *Streptanthella*
2 At least some of the leaves toothed, lobed, or pinnatifid
3 Leaves toothed at the apex, not lobed, those of the stem strongly auriculate-clasping ..... *Streptanthus*
3 At least some of the leaves lobed or pinnatifid, not auriculate at the base (the upper ones cordate-clasping in *Lepidium perfoliatum*)
4 Plants 2-20 cm tall, annual or winter annual; leaves to 3.5 cm long, or if longer then tripinnatifid ..... *Lepidium*
4 Plants (20) 30-80 cm tall, annual or perennial; leaves often 3-15 cm long, lobed or once pinnatifid
5 Plants glabrous or nearly so, glaucous, perennial; stems not inflated; petals bright yellow ..... *Stanleya*
5 Plants hirsute with spreading hairs or if glabrous then stems inflated; petals purplish or brownish ..... *Caulanthus*
1 Plants pubescent with forked, branched, or stellate hairs
6 Leaves dissected into numerous fine segments ..... *Descurainia*
6 Leaves entire to toothed
7 Leaves sessile and auriculate at the base
8 Plants annual, introduced ..... *Camelina*
8 Plants perennial, native ..... *Arabis*
7 Leaves petioled or sessile but not auriculate at the base
9 Plants perennial, grayish or whitish, covered with dense, overlapping, appressed, stellate hairs; leaves elliptic to broadly oblanceolate, more or less constricted to a petiole; petals yellow

10 Blades of lower leaves 4-10 mm long, 2-6 (10) mm wide; petioles 4-15 mm long, rarely longer ..... *Lesquerella*
10 At least some of the lower leaves larger than above ..... *Physaria*
9 Plants annual, biennial, or short-lived perennial, if perennial then leaves linear to narrowly oblanceolate and sessile or gradually tapered to an indistinct petiole; pubescence of forked, pick-shaped or branched hairs
11 Plants annual with forked or branched hairs; leaves sometimes toothed; petals white or purple
12 Leaves crowded at the base of the plant; plants 2-5 (7) cm tall, native; petals white ..... *Draba*
12 Leaves not crowded at base of plant; plants 3-25 cm tall, introduced, weedy on disturbed sites; petals purple ..... *Malcolmia*
11 Plants biennial or short-lived perennials with pick-shaped hairs that are attached near the middle with a short stalk (the stalk serves as a pivot and when one end of the hair is moved the opposite end moves about an equal distance—a feature not easily detected without a dissecting scope); petals yellow ..... *Erysimum*

Arabis L. Rockcress

Perennial herbs usually with at least some forked, branched, or dendritic hairs; leaves alternate, entire or inconspicuously toothed; petals white, pink, or purple; fruit linear, many-seeded.

1 Lower leaves hirsute-ciliate with simple or once-forked hairs; stems and leaf surfaces glabrous or with simple or forked hairs; pods 1-4 cm long, pendulous; pedicels and fruit glabrous; plants rare on DER; petals about 5-7 mm long ..... *A. pendulina*
1 Lower leaves not ciliate exclusively with simple or once-forked hairs; lower part of stems and leaf surfaces of at least lower leaves with forked, branched, or dendritic hairs; pods various; petals various; pedicels and fruit glabrous or pubescent
2 Stem leaves not auriculate, not crowded; basal rosette of leaves poorly developed; petals 9-11 mm long, lavender to purple; herbage and usually the pedicels, ovaries, and pods densely pubescent with minute dendritic hairs; pods 35-65 mm long, pendulous to reflexed ..... *A. pulchra*
2 Stem leaves auriculate, sometimes crowded; basal rosette mostly well developed; petals 5-10 mm long, pink to lavender; pubescence not as above except in *A. shockleyi* and then the basal rosette well developed
3 Herbage, pedicels, and sometimes fruit densely pubescent with minute soft hairs; petals 7.5-10 mm long; pods 42-65 mm long, ascending to spreading; leaves and fruit usually densely crowded ..... *A. shockleyi*
3 Pubescent different from above in one or more ways; petals 5-9 mm long; pods 20-65 mm more or less spreading-pendulous; leaves crowded or not
4 Stems usually 3 or more, arising from between the basal rosette and a secondary tuft of leaves ..... *A. perennans*
4 Stems usually solitary or to 3, arising from the basal rosette, the secondary tuft of leaves lacking ..... *A. lignifera*

***Arabis lignifera* A. Nels.** Woody rockcress. Occasional in hills.

***Arabis pendulina* Greene** The two records seen are from the east side of Tunnel Springs Mountain; pinyon-juniper community. May through June.

***Arabis perennans* Wats.** The few records seen are from Tunnel Springs Mountain and Warm Cove Ridge; pinyon-juniper and desert shrub communities. May through June.

***Arabis pulchra* Jones var. *munciensis* Jones** Beauty rockcress. Infrequent or rare, the two specimens seen are from Warm Cove Ridge and Halfway Hills. May through June.

***Arabis shockleyi* Munz** Shockley rockcress. Infrequent on Tunnel Springs Mountain in pinyon-juniper and mahogany communities. May through June.

Camelina Crantz False Flax

***Camelina microcarpa* Andrz. in DC.** Little false flax, hairy false flax. Annual herbs, 8-80 cm tall, with simple, forked, or stellate hairs; leaves entire or obscurely toothed, about 1-8 cm long, at least the upper ones auriculate; petals white or cream, 3-5 mm long; fruit slightly inflated, glabrous, 5-7 mm long, pointed at the tip into a short style. Introduced from Asia, infrequent, more or less weedy about Headquarters and perhaps along roads.

Caulanthus Wats. Wild Cabbage; Caulanthus

Herbs; at least the lower leaves pinnatifid, those of the stem petiolate and not auriculate; pods linear, long.

1 Plants glabrous and more or less glaucous, mostly winter annual or biennial (on DER) or short-lived perennial (elsewhere); stems usually strongly inflated; petals dull-purplish, 10-14 mm long; stem leaves conspicuously reduced upward on the stem ..... *C. crassicaulis*

1 Plants hirsute to pilose at least below, winter annual or biennial; stems not inflated; petals white, suffused with purple or pink, 7.5-10 mm long; stem leaves only slightly reduced upward ..... *C. pilosus*

***Caulanthus crassicaulis* (Torr.) Wats. var. *glaber* Jones** Thickstem wild cabbage. Infrequent in some years, the three specimens seen are from near Bullgrass Knoll and east side of Antelope Valley near Tunnel Springs Mountain.

***Caulanthus pilosus* Wats.** Occasional and widely scattered in some years, valleys and fans. May through June.

Descurainia Webb & Berth. Tansy Mustard

Winter annual or biennial herbs, usually stellate pubescent; leaves 1-3 times pinnately compound or pinnatifid; petals yellow; fruit linear or linear-elliptic.

1 Pods (15) 20-30 mm long; upper as well as lower leaves 2-3 times pinnate; plants introduced ..... *D. sophia*

1 Pods 3-15 mm long; upper leaves only once pinnate; plants native ..... *D. pinnata*

***Descurainia pinnata* (Walt.) Britt.** (*Sophia pinnata* [Walter] Howell) Pinnate tansy mustard. With two intergrading varieties on the DER.

1 Stems and branches stipitate glandular in the inflorescence with tack-shaped hairs; pubescence of leaves often dense enough to give grayish cast to the leaves ..... var. *osmiarum*

1 Plants not glandular, tack-shaped hairs lacking; pubescence of leaves rarely dense enough to give grayish cast to the leaves ..... var. *intermedia*

Var. *intermedia* (Rydb.) C.L. Hitchc. All specimens seen are from hills and Tunnel Springs Mountain. May through June.

Var. *osmiarum* (Cockerell) Shinners (*D. p.* var. *halictorum* [Cockerell] Peck) All specimens seen are from Pine Valley, especially in areas of frequent rodent disturbance. May through June.

***Descurainia sophia* (L.) Webb in Engler & Prantl** (*Sophia parviflora* [Lam.] Standl.) Introduced from Eurasia, weedy, most commonly seen near DER Headquarters and occasionally in other areas of supplemental watering (flood plains in valleys at the ends of major washes). May through June.

Draba L. Whitlow-grass; Whitlow-wort; Draba

***Draba cuneifolia* Nutt. ex T. & G.** Wedgeleaf draba. Annual herbs 1-5 (10) cm tall; leaves crowded towards the base of stems and sometimes appearing all basal; entire to dentate, hirsute with 2- to 4-rayed hairs and sometimes simple hairs; flowers 3-many; petals 3-5 mm long, white; pods 4-15 mm long, about 2-4 mm wide. Occasional, mostly in swales of hills and fans. March through May.

Erysimum L. Wallflower

***Erysimum asperum* (Nutt.) DC.** Rough wallflower, prairie rocket. (*E. capitatum* [Dougl.] Greene; *E. argillosum* [Greene] Rydb.; *Cheirinia bakeri* [Greene] Rydb.; *C. elata* (Nutt.) Rydb.; *C. oblanceolata* Rydb.; *C. wheeleri* [Roth.] Rydb.) Biennial or short-lived perennial herbs, 10-30 cm tall, rarely taller on DER, pubescent with 2-rayed or pick-shaped (malpighian) hairs; leaves entire, 1-5 (10) cm long, mostly linear or at least narrow; flowers usually several; petals yellow, 12-20 (28) mm long; pods 17-60 cm long or longer, many-seeded. Occasional, hills, valleys, and fans. April through June. DER plants are referable to var. *purshii* Durand.

Lepidium L. Peppergrass; Pepperweed

Annual, winter annual, biennial, or rarely short-lived perennial plants, glabrous or with simple hairs only; winter rosettes usually well developed, and green through much or all of the winter; leaves pinnately lobed to divided, some usually simple; petals small or lacking; pods ovate to elliptic, short, 2-seeded.

1 Upper leaves strongly cordate-clasping, entire, ovate; basal leaves tripinnatifid; petals yellow ..... *L. perfoliatum*
1 Leaves not cordate-clasping, the basal ones entire or toothed to once-pinnatifid; petals white or lacking
2 Pods not notched at apex, not at all winged; style evident as a point on the pod; petals longer than the sepals; at least some of the lower leaves usually divided to the midrib, the lobes often linear or narrowly oblanceolate; plants annual, biennial (DER), or short-lived perennial (elsewhere) ..... *L. montanum*
2 Pods notched at the apex, more or less winged on upper margins; styles not evident, not exceeding the notch; petals obsolete or shorter than the sepals; leaves entire, toothed, or if lobed then not cut more than about half way to the midrib, and the lobes usually rounded; plants annual or winter annual .... *L. densiflorum*

***Lepidium densiflorum* Schrad.** Prairie pepperweed. Common in some years, disturbed places and near washes. May through June.

Lepidium montanum* Nutt. var. *montanum Mountain pepperweed. (*L. scopulorum* Jones f. *nanum* Thell.; *L. albiflorum* Nels. & Kenn.) Common, widespread through many plant communities in Pine Valley, but seldom abundant except on areas of rodent activity, seen in most years. May to mid-July.

***Lepidium perfoliatum* L.** Clasping pepperweed. Introduced from Europe, infrequent or locally common in some years near Headquarters. May through June.

Lesquorella Wats. Bladderpod

***Lesquerella goodrichii* Rollins** Perennial herbs, 2-5 (8) cm tall, densely stellate pubescent, stems decumbent to ascending; lower leaves gradually or rather abruptly tapered to a petiole, the blades about 4-10 mm long, 2-6 mm wide, the upper leaves sessile and reduced; petals yellow, 6-8 mm long; fruit 3-6 mm long; style 2-4 mm long. Occasional, Tunnel Spring Mountain, pinyon-juniper and mahogany communities. May through June. The type specimen (Goodrich 16951) is from the DER.

Malcolmia (L.) R. Br. Malcolmia

***Malcolmia africana* R. Br. in Ait.** African mustard. Annual herbs, 3-40 cm tall, pubescent with forked or 3-rayed hairs; leaves sinuate-dentate, 1.2-9 cm long, 0.3-2.3 cm wide, oblanceolate to elliptic, petioled or sessile, not auriculate; petals 6-10 mm long, pink to lavender; pods 33-66 mm long. Introduced from Africa, weedy, adventive along roads and on other disturbed ground. May through June.

Physaria (Nutt.) Gray Twinpod; Double Bladderpod

***Physaria chambersii* Rollins** Great Basin twinpod. (*P. didymocarpa* [Hook.] Gray in part) Perennial herbs, 3-25 cm tall, densely pubescent with stellate hairs; basal leaves 1-8 cm long, 0.3-3.5 cm wide, orbicular to elliptic, entire, or toothed; stem leaves much reduced; petals yellow; pods strongly inflated. Occasional, mostly on hills and upper parts of fans. April to mid-May.

Stanleya Nutt. Prince's Plume; Stanleya

***Stanleya pinnata* (Pursh) Britton.** Brushy stanleya. Perennial herbs, the base more or less woody, glabrous to pilose, glaucous; leaves mostly 5-10 (18) cm long, 2-5 cm wide, pinnatifid or the upper ones entire; petals yellow, 11-17 mm long; pods 3-7 cm long. Rare on DER, hills and upper parts of fans, common in volcanic soils of the area. Late May through June.

Streptanthella Rydb. Streptanthella

***Streptanthella longirostris* (Wats.) Rydb.** Beaked streptanthella. (*Streptanthus longirostris* Wats.) Annual herbs, 10-50 cm tall, glabrous; leaves 1.5-8.5 cm long, 1-12 mm wide, oblanceolate to elliptic or nearly linear, entire to sinuate-dentate; petals 5-8 mm long, white with purplish veins; pods 3-6 cm long, reflexed-descending, with a 3-7 mm long beak. Occasional or infrequent at least in some years, sandy places, valleys, and lower parts of fans. May through June.

Streptanthus Nutt. Streptanthus

***Streptanthus cordatus* Nutt. in T. & G.** Heartleaved streptanthus. Perennial herbs, glabrous, glaucous, 15-30 (60) cm tall; basal leaves 1.5-8 cm long, 0.5-3 cm wide; dentate at the apex; stem leaves sessile and strongly auriculate; petals 10-15 mm long, purplish to brownish; pods 5-8.5 cm long. Infrequent, the few specimens seen are from Halfway Hills and Tunnel Springs Mountain. May through June. Grazed moderately to heavily by antelope while flowering.

CACTACEAE; CACTUS FAMILY

Plants perennial, succulent, spiny; stems fleshy with a thick epidermis, with areoles (spine-bearing areas); leaves obsolete or lacking; flowers mostly showy, bisexual; petals numerous; stamens numerous; pistil 1, the ovary inferior; style 1, with 4-12 stigmas.

1 Stems jointed, the joints (1) 2-several, flattened or cylindrical; areoles bearing both spines and glochids (retrorsely barbed stiff fine hairs), subtended by terete early deciduous green leaves when young ..... *Opuntia*
1 Stems not jointed, cylindrical or spherical; areoles borne on ribs or tubercules, with spines or hairs but without glochids
  2 Stems longitudinally ribbed, more or less cylindrical, not much if at all buried in the ground; flowers borne on spine-bearing areoles below the apex of the stem; floral tube spiny ..... *Echinocereus*
  2 Stems tuberculate (the tubercules more or less spirally arranged), more or less spherical or hemispherical (pincushionlike), often half or more buried in the ground; flowers borne at or near the apex of the stem; floral tube not spiny
    3 One of the central spines of at least some areoles hooked; central spines 1-5; radial spines about 5-12 per areole, not obscuring the surface of the stem ..... *Sclerocactus*
    3 Spines not hooked, central spines 1-12; radial spines 10-30 per areole, often more or less obscuring the surface of the stem
      4 Tubercules grooved; flowers 3.8-5 cm wide, axillary at tubercule base, at end of a felty persistent groove connected to the areole; petals pink-purple to rose, linear-lanceolate, acute ..... *Coryphantha*
      4 Tubercules not grooved; flowers less than 3 cm wide, borne at the tubercule apex on one side of areole; petals whitish, pinkish, yellowish, or greenish, wider than lanceolate, rounded at the tip; specimens not seen from the DER but from nearby hills ..... *Pediocactus simpsonii* (Engelm.) Britt. & Rose

Coryphantha Lem. Coryphantha

***Coryphantha vivipara* (Nutt.) Britt. & Rose var. *arizonica* (Engelm.) W. T. Marshall** Cushion coryphantha. Stems more or less spherical or hemispherical, strongly tuberculate, 2-5 cm tall, rarely taller at DER, half or more often buried in the ground; tubercles 6-9 mm long; central spines whitish basally, dark apically, about 12-20 mm long; radial spines 12-20, spreading, obscuring the stem; fruit fleshy, green, ellipsoid, 12-25 mm long. The linear-lanceolate, acuminate petals are unique among the cactuses of the DER. Rare but scattered in a number of plant communities, hills and alluvial fans. June.

Echinocereus Engelm. Hedgehog Cactus; Barrel Cactus

Stems mostly cylindrical and slightly elongate, about 10-15 (20) cm long and 5-8 cm thick (in those at DER), strongly longitudinally ribbed, the ribs parallel; fruit fleshy, spiny, green or red.

1 Flowers scarlet-red; stems few to numerous in compact clusters or colonies, to 10 (15) cm tall ..... *E. triglochidiatus*
1 Flowers pink-purple to rose; stems solitary or few together, 10-20 cm tall ..... *E. engelmannii*

***Echinocereus engelmannii* (Parry) Rumpler var. *chrysocentrus* (Engelm. & Bigel.) Engelm. ex Rumpler** Infrequent, mostly in coarse gravels of washes in upper parts of fans. Mid-June.

***Echinocereus triglochidiatus* Engelm. var. *melanacanthus* (Engelm.) L. Benson** Claret-cup echinocereus. (*E. coccineus* Engelm.) Infrequent or rare, mostly restricted to cracks in dolomite outcrops. May through June.

Opuntia Mill. Pricklypear

Stems jointed, areoles armed with spines and glochids (small retrorsely barbed stiff hairs), the glochids tufted; flowers borne in areoles of previous year's growth; fruit fleshy or dry.

1 Joints cylindrical or club-shaped; spines with detachable sheaths (at least at the apex); fruit fleshy
  2 Joints 1-3, rarely more, club-shaped; plants 3-10 cm tall, armed with rather slender spines; petals rose-pink to orchid; fruit red, spiny ..... *O. pulchella*
  2 Joints often more than 3, cylindrical; plants 10-60 cm tall, armed with stout spines; petals yellowish-green; fruit yellow, glochidiate ..... *O. whipplei*

1 Joints strongly flattened; spines with persistent sheaths; fruit dry, tan or brown, spiny ..... *O. polyacantha*

***Opuntia polyacantha* Haw.** Plains pricklypear. Not common, but scattered in many plant communities, valleys, benches, and hills. June.

***Opuntia pulchella* Engelm.** Finger cactus, sand cholla. (*Micropuntia barkleyana* Daston; *M. brachyropalia* Daston; *M. spectatissima* Daston) Occasional, widespread, gravelly alluvium and dolomite hillsides. Late May to early June. The stems arise from a tuberous root.

Opuntia whipplei* Engelm. & Bigel. var. *whipplei Whipple cholla. Occasional to locally common on rocky slopes on light colored quartzite of Warm Cove Ridge, also on volcanics just off the DER in Red Hills. June.

Sclerocactus Britt. & Rose Sclerocactus

***Sclerocactus pubispinus* (Engelm.) L. Benson** (*Echinocactus pubispinus* Engelm.; *S. whipplei* [Engelm.] Britt. & Rose) Stems mostly solitary, depressed hemispheric to ovoid, half or more often buried below ground level, 1-5 cm tall, rarely taller on DER, with 6-13 ribs; young spines and often some older ones sparingly to densely white-pubescent; flowers 2.5-3.5 cm long; petals yellow, bronze, pink or violet to rose-purple; fruit dry. Most of the DER material is referable to var. *pubispinus* with flowers bronze to yellow, and with widest upper central spines 0.7-1 mm wide. However, a few specimens seen are transitional to var. *spinosior* (Engelm.) Welsh, which has flowers rose to violet and widest upper central spines 1-2.2 mm wide. Rare, scattered, hills and upper parts of fans.

CAPPARIDACEAE; CAPER FAMILY

Cleome L. Spiderflower; Bee-plant

***Cleome serrulata* Pursh** Bee spiderflower. Annual herbs, 30-80 cm tall or taller; leaves alternate, with 3-7 palmate leaflets, the leaflets 2-7 cm long, lanceolate to oblanceolate, mostly entire; flowers in racemes; petals purplish-pink, occasionally white, 10-12 mm long; stamens long-exserted; fruit (capsule) linear, many seeded, 2.5-6.5 cm long, stipitate, the stipe to as long as the pedicel. Roadsides, rare on DER, common along Highway 21.

CAPRIFOLIACEAE; HONEYSUCKLE FAMILY

Symphoricarpos Duhamel Snowberry

***Symphoricarpos longiflorus* Gray** Longflower snowberry. Much-branched shrubs, 50-100 cm tall, twigs and leaves opposite; leaves 6-15 mm long, 3-5 mm wide, simple, entire; corollas united, 11-13 mm long, narrow, pink; fruit a berrylike drupe, white, 8-10 mm long. Occasional, among rocks, and on rocky slopes in hills and along washes at upper edge of fans. May through June.

CARYOPHYLLACEAE; PINK FAMILY

Perennial herbs (on DER); leaves opposite, linear; sepals and petals free or petals obsolete.

1 Leaves 3-6 mm long, densely crowded, with prominent scarious stipules; plants not over 5 cm tall, pulvinate caespitose to spreading and mat forming; flowers sessile, inconspicuous, hidden among the leaves; petals obsolete; stamens 5 ..... *Paronychia*

1 Leaves 10-20 mm long or longer, without scarious stipules; plants 10-20 cm tall, more or less caespitose but not pulvinate; flowers in open cymes, conspicuous, petals more or less showy, about 5-10 mm long, white; stamens 10 ..... *Arenaria*

Arenaria L. Sandwort

***Arenaria kingii* (Wats.) Jones** Kings sandwort. With features of the family and as listed in the key. Occasional to rather common, widespread in hills. April through June.

Paronychia Adans. Whitlow-wort; Nailwort

***Paronychia sessiliflora* Nutt.** Creeping nailwort. With features of the family and as listed in the key. The few specimens seen are from exposed, rocky places on Warm Cove Ridge.

CELASTRACEAE; STAFFTREE FAMILY

Forsellesia Greene Greasebush

***Forsellesia nevadensis* (Gray) Greene** Nevada greasebush. (*Glossopetalon nevadensis* Gray) Spiny much branched shrubs to about 50 cm tall; twigs green, yellowish in age, puberulent; leaves alternate, simple, entire, 5-12 mm long, oblong to oblanceolate; flowers axillary, inconspicuous; petals 4-7 mm long, whitish, quickly deciduous; fruit a follicle to 5 mm long. Common to abundant in hills, mostly on Warm Cove Ridge. May through June.

CHENOPODIACEAE; GOOSEFOOT FAMILY

Shrubs or forbs; leaves mostly alternate, rarely opposite, simple, entire, toothed, or lobed; flowers axillary or more often glomerate in a spicate or racemose to paniculate inflorescence, inconspicuous, perianth of a single set (sepals); stamens generally equal to and opposite the perianth lobes; ovary superior; fruit an utricle.

1 Plants annual herbs
- 2 Leaves glabrous or with nonscurfy hairs, linear to terete, often tipped with a hairlike bristle or spinelike point, not over 3 mm wide, more or less succulent at least when young; fruit with a horizontal wing
  - 3 Leaves 5-10 mm long, tipped with a bristlelike hair, the tip not spiny in age, terete or nearly so; plants not becoming spiny in age, remaining succulent even during flowering and fruiting, well into autumn ..... *Halogeton*
  - 3 Leaves sometimes over 10 mm long, tipped with a sharp point that sometimes becomes spiny in age, terete to linear; plants succulent when young, becoming spiny, hardened as flowering starts in late summer, drying to a tumbleweed ..... *Salsola*
- 2 Leaves either scurfy or broader than linear and usually both, not tipped with bristlelike hairs or spines; fruit not with horizontal wings
  - 4 Leaves irregularly lobed, at least some of the lobes cut ¼-¾ the way to the midrib; perianth lobes 1 ..... *Monolepis*
  - 4 Leaves entire or lobed less than ¼ the way to the midrib
    - 5 Plants pubescent, often densely so ..... *Kochia*
    - 5 Plants glabrous or scurfy
      - 6 Flowers bisexual with a regular (3-4) 5-lobed perianth; leaves entire or with rounded teeth or lobes; seeds blackish and shiny ..... *Chenopodium*
      - 6 Flowers unisexual, the pistillate ones more or less enveloped by 2 bracts; leaves with rather pointed lobes or teeth; seeds not blackish and shiny ..... *Atriplex*

1 Plants perennial shrubs or subshrubs
- 7 Leaves glabrous, green, fleshy-succulent, linear to subterete, not over 2 mm wide; those persisting into winter dry to black or dark brown; fruit with a horizontal wing
  - 8 Shrubs more or less spiny, 0.3-1 m tall or taller ..... *Sarcobatus*
  - 8 Subshrubs, not over 0.3 m tall ..... *Kochia*
- 7 Leaves either densely scurfy or otherwise pubescent, whitish or grayish, succulent or not; fruit various
  - 9 Leaves and twigs glabrate to densely tomentose, hirsute or sericeous, but not scurfy; leaves linear or nearly filiform; plants suffrutescent subshrubs
    - 10 Leaves and twigs stellate-tomentose; leaves linear, slightly to strongly revolute, the midnerve conspicuous beneath ..... *Ceratoides*
    - 10 Leaves glabrate to sericeous with simple hairs, terete or nearly so or subulate, often without a conspicuous midnerve ..... *Kochia*
  - 9 Plants scurfy, the hairs inflated and soon collapsing and leaving a grayish or whitish mealy coating on leaves and twigs; leaves linear or broader; plants half shrubs or shrubs
    - 11 Plants mostly spiny; leaves oblanceolate to orbicular
      - 12 Leaves scurfy when young, some of the hairs forked or stellate, glabrate or glabrous and green when mature, mostly oblanceolate to spatulate, deciduous by midsummer; bark of twigs exfoliating in long, white strips; bracts of fruit wholly united into a sac ..... *Grayia*
      - 12 Leaves permanently and densely gray-white scurfy with simple, inflated (but collapsing) hairs, mostly ovate to obovate, most persisting, not

summer-deciduous; bark not as above; bracts of fruit free toward the apex ..... *Atriplex confertifolia*

11 Plants not or only weakly spiny; leaves linear, 3-10 times longer than wide ..... *Atriplex*

Atriplex L. Orache; Saltbush

Annual herbs to shrubs; leaves mostly alternate, rarely opposite, entire to toothed, densely scurfy, pale gray-green; flowers bisexual, the staminate ones with a perianth, the pistillate without a perianth, but enclosed in two bracts.

1 Plants annual herbs; leaves sinuate-dentate the whole length, ovate, elliptic, lanceolate, or nearly rhombic ..... *A. rosea*

1 Plants shrubs or subshrubs

2 Plants spiny; leaves obovate to orbicular ..... *A. confertifolia*

2 Plants not spiny or only weakly so; leaves linear or nearly so

3 Fruiting bracts with 4 wings

4 Fruiting bracts including the wings over 9 mm wide, tips of the bracts not exceeding the wings; staminate flowers yellow; plants shrubs, widespread ..... *A. canescens*

4 Fruiting bracts including the wings less than 9 mm wide, tips of bracts exceeding the wings; staminate flowers mostly brownish; plants shrubs or sometimes herbaceous above, restricted to the area of Pine Valley Hardpan ..... *A. bonnevillensis*

3 Fruiting bracts not winged, toothed at apex ..... *A. falcata*

***Atriplex bonnevillensis* C. A. Hanson** Bonneville saltbush. Locally common around Pine Valley Hardpan. July through August. This taxon seems to be of rather recent hybrid derivation involving *A. canescens* and *A. falcata*. The taxon is functional but unstable and shows a range of features that approach those of *A. canescens* on one extreme and those of *A. falcata* on the other. The type specimen (Hanson 354) is from Pine Valley playa. Sheep and cows browse *A. bonnevillensis* while on the DER in winter, and might in summer if they were still there.

***Atriplex canescens* (Pursh) Nutt.** Fourwing saltbush. Occasional to common, mostly in gravelly washes and sandy ground. June. The leaves persist through much or all of winter and the leaves and twigs are grazed by sheep and cattle.

***Atriplex confertifolia* (Torr. & Frem.) Wats.** Shadscale. Common to abundant, many plant communities, valleys, fans, and hills. June. Leaves persist through winter following summers and autumns of greater than normal precipitation. Palatable to sheep, but the growth is not always available, for in years of poor growth the older spines prevent access to the leaves and succulent twigs. Shadscale has increased in abundance under heavy and repeated sheep use. It has become dominant where *Artemisia nova, A. spinescens,* and *Ceratoides lanata* have declined under heavy use.

***Atriplex falcata* (Jones) Standl.** (*A. nuttallii* Wats. var. *falcata* Jones; *A. nuttallii* ssp. *falcata* H. & C.) Locally common in the bottom of Pine Valley near the hardpan. June. Used by sheep and cattle.

***Atriplex rosea* L.** Tumbling orache. Introduced from Eurasia, more or less weedy on disturbed ground, rare on DER. August-September

Ceratoides Winterfat; White Sage; Winter Sage

***Ceratoides lanata* (Pursh) J. T. Howell var. *subspinosa* (Rydb.) J. T. Howell** (*Eurotia lanata* [Pursh] Moq.) Suffrutescent long-lived subshrubs, 15-30 cm tall, rarely taller on DER; current twigs and leaves densely stellate tomentose and also with longer, simple, straight hairs; leaves simple, alternate, linear or nearly so, 1-4 cm long, revolute, the midnerve conspicuous beneath; flowers inconspicuous, the staminate ones with a 4-parted perianth, the pistillate ones with 2 united pilose bracts; stamens 4; stigmas 2; fruit covered with long soft white hairs. Common, widespread, valleys, fans, and lower hills, sometimes in nearly pure stands on loamy fine sand in valley bottoms. April through June. Starts growth early in spring and grows any time in summer and fall after sufficient precipitation. Years of abundant seed production are rare. In most years palatable winter-long to cattle, sheep, and horses, and every year in late winter and spring. Winterfat endures more severe grazing than other shrubs, but it has declined in number and productivity of surviving plants under severe grazing pressure.

Chenopodium L. Goosefoot; Pigweed; Lambsquarters

Annual herbs; leaves alternate, more or less scurfy; flowers inconspicuous; stamens 1-5; styles usually lacking; stigmas 2-5; seeds blackish, usually shiny.

1 Lower leaves more or less cordate to truncate basally, glabrous, green, the margins with large teeth or small lobes . . . . . *C. hybridum*
1 Leaves not cordate or truncate basally, or if so then usually grayish or whitish scurfy, the margins entire to toothed or hastately lobed
  2 Leaf blades lobed toward the base, otherwise entire or the hastate lobes sometimes with a smaller lobe or tooth; pericarp not adherent to the seed . . . *C. fremontii*
  2 At least the larger leaves sinuate-dentate above the base, sometimes also subhastately lobed toward the base; pericarp adherent to the seed . . . . . *C. album*

***Chenopodium album* L.** Lambsquarters. Introduced from Eurasia, more or less weedy on disturbed ground. This summer annual is not seen in most years.

***Chenopodium fremontii* Wats.** Fremont goosefoot. (*C. incanum* [Wats.] Heller) More or less weedy on disturbed ground. This summer annual is not seen in most years.

***Chenopodium hybridum* L.** Mapleleaf goosefoot. (*C. gigantospermum* Aellen) The one specimen seen (S. Welsh and G. Moore 3164 BRY) is from the west side of Tunnel Springs Mountain.

Grayia H. & A. Hopsage

***Grayia spinosa* (Hook.) Moq. in DC.** Spiny hopsage. (*Atriplex spinosa* [Hook.] Collotzi) Shrubs 60-100 cm tall; bark of twigs exfoliating in white strips; leaves 1-3 cm long, linear oblanceolate, spatulate or obovate, scurfy when young, glabrate in age; flowers inconspicuous; fruiting bracts 5-12 mm long, usually over 5 mm wide, glabrous, greenish, often reddish in age. Common in a few areas of coarse-sandy soils, especially in and west of the Red Hills. May through June. The leaves and fruit are usually deciduous by July. This is palatable to sheep after spring growth starts, but in most years the sheep have left before growth starts.

Halogeton C. A. Mey. Halogeton

***Halogeton glomeratus* (Bieb.) Mey. in Ledeb.** Annual herb, succulent, 3-30 cm tall, with branched stems, glabrous except tomentose in leaf axils; leaves 5-10 mm long, about 1-3 mm wide, alternate, terete or nearly so, entire, with a single hairlike bristle at the apex; flowers inconspicuous, unisexual or bisexual, in axillary clusters; perianth segments 5; stamens 3 or 5; stigmas 2; fruit encompassed by a scarious, horizontal, 3-4 mm wide wing. Introduced from Eurasia, adventive on disturbed ground, most common along roadways, flooded outwash areas in valley bottoms, areas of rodent disturbance, and where perennial plant cover has been reduced by abusive grazing; abundant and productive on these areas in years of greater than normal summer moisture. Poisonous to sheep, but sheep losses from halogeton have not been documented from the DER.

Kochia Roth.

1 Plants annual herbs, sparingly introduced . . . . . *K. scoparia* (L.) Schrad.
1 Plants perennial, more or less woody at the base
  2 Plants branched in the inflorescence, 10-75 cm tall, introduced (a single plant seen at the gaspump at Headquarters in 1983); stems often reddish in age . . . . . *K. prostrata* (L.) Schrad.
  2 Plants not branched in the inflorescence, 10-30 cm tall, native; stems seldom reddish . . . . . *K. americana*

***Kochia americana* Wats.** Gray molly, green molly. Perennial subshrubs, dying back to lower woody part of crown in winter, sericeous to glabrate; leaves alternate, 5-25 mm long, about 1 mm wide, terete; flowers inconspicuous, bisexual or some pistillate, solitary or few in axils of leaves; perianth 5-lobed, persistent; stamens 3-5; stigmas 2-3; fruit encompassed by a horizontal wing. Occasional to dominant on and around Pine Valley Hardpan and valleys, infrequent in small patches on lower hills and fans. Moderately palatable to sheep and cattle in winter (when the herbage is dark brown to black). The glabrate phase is referable to var. *americana*. The pubescent phase is referable to var. *vestita* Wats. (*K. vestita* Rydb.).

Monolepis Schrad. Monolepis; Poverty Weed

***Monolepis nuttalliana* (Schult.) Greene** Annual herbs, stems few to several from the base, ascending, succulent, mealy when young, 5-20 cm long; leaves 1-4 cm long, usually hastately lobed at the base; flowers in dense axillary clusters and in terminal interrupted spikes, the clusters often reddish in age; perianth inconspicuous; seeds dark. Rare or occasional in some years on volcanic soils of the Red Hills. May through July.

Salsola L. Russian Thistle; Tumbleweed

Annual herbs, succulent to spiny tumbleweeds; leaves linear to terete; flowers inconspicuous, borne in axils of subulate spine-tipped bracts along open terminal spikes, bisexual; fruit encompassed by a horizontal wing (calyx wings).

1 Plants (from seedling to time of flowering) neither rigid nor prickly, appearing taller than wide, narrowed toward the apex with the central stem longer than the slender, ascending lateral branches, soft to the touch until late summer, blue-green in color; stems often with longitudinal red-purple lines; young leaves less than 1 mm wide, subterete, weakly spine-tipped, 1-3 cm long, becoming more rigid at maturity, and replaced in the inflorescence by short, pungent, rigid, broad bracts; flowers appearing in August to early September, 2-3 weeks later than in the following; fruiting calyx-wings small, mostly less than 2 mm long, sometimes deep red ..... *S. iberica*

1 Plants rigid and prickly to the touch from seedling through maturity, appearing as wide as tall and convex topped with the stout, strongly spreading to decumbent lateral branches as long as the central stem, yellow-green in color; stems without purple lines or the lines pale; leaves from seedling stage through maturity, thick, terete, rigid, recurved toward the apex, strongly pungent-tipped, 0.5-1.5 cm long, 1-1.5 mm wide; flowers appearing in July and August; fruiting calyx-wings large, 3-4 mm long, colorless to pale pink, with conspicuous veins ..... *S. paulsenii*

***Salsola iberica* Sennen & Pau** Russian thistle, tumbleweed. (*S. pestifer* A. Nels.; *S. kali* L. misapplied). Introduced from Russia, weedy along roads and other disturbed areas. July through September.

***Salsola paulsenii* Litv.** Barbwire Russian thistle. Introduced from Russia and central Asia, weed along roads and in other disturbed areas. July through August.

Sarcobatus Nees. Greasewood

***Sarcobatus vermiculatus* (Hook.) Torr.** Greasewood, black greasewood. Spiny much branched shrubs with rigid stems, 0.3-1.5 m tall, rarely taller on DER; twigs of the season green and succulent at first, turning white and spiny before the start of the second season; leaves 1-4 cm long, 1-3 mm wide, linear, entire, slightly flattened to nearly terete, glabrous, green, fleshy-succulent; flowers inconspicuous, unisexual, the staminate in conelike or catkinlike spikes, these 5-25 mm long, the pistillate 1-2 in axils of leaves; fruit encompassed by a horizontal, scarious, 6-12 mm long wing. Common at Pine Valley Hardpan, rare in hills. May through August.

CUPRESSACEAE; CYPRESS FAMILY

Juniperus L. Juniper

***Juniperus osteosperma* (Torr.) Little** Utah juniper, boneseed juniper, white cedar. (*J. utahensis* [Engelm.] Lemmon) Shrubs to small trees, with shredding fibrous bark; leaves evergreen, scalelike, mostly not over 3 mm long, strongly overlapping and appressed to the twigs, appearing as a scaly covering on the twigs, aromatic, opposite; pollen-bearing cones 3-4.5 mm long, yellowish-brown, with 13-24 microsporophylls (much reduced and modified leaf that bears a spore that gives rise to a male gametophyte); seed-bearing cones berrylike, globose or ovoid, bluish, bluish-white, to reddish-brown, glaucous, with 1 (2) seeds. Dominant or codominant with singleleaf pinyon on Tunnel Springs Mountain, rare in other hills. Apparently sensitive to cold temperatures of long duration and not found in valleys or lower hills where cold air drainage is common in winter. Used occasionally by antelope.

CYPERACEAE; SEDGE FAMILY

Carex L. Sedge

***Carex rossii* F. Boott** Ross sedge. Plants perennial, grasslike, 3-10 cm tall, rarely taller at DER, reddish or purplish at the base, caespitose; leaves basal and on lower part of stems, linear, 1-4 mm wide; flowers inconspicuous, borne in unisexual spikes, the staminate ones consisting of 3 stamens subtended by a scale, the pistillate ones consisting of an ovary enclosed in a pubescent sac (perigynia). Occasional, Tunnel Springs Mountain in pinyon-juniper communities. May through June. (An unidentified *Carex* grows at Headquarters by a leaky tap.)

EPHEDRACEAE; EPHEDRA FAMILY

Ephedra L. Ephedra; Mormon Tea; Jointfir

Shrubs with yellowish, bluish, or greenish opposite or whorled twigs; leaves reduced to readily deciduous opposite scales, and thus usually lacking; stamens and seeds borne in unisexual cones.

1 Branches divergent; glaucous, blue-green or gray-green; base of mature leaves light brown to gray, deciduous ..... *E. nevadensis*
1 Branches erect or strongly ascending, broomlike, yellowish-green to green becoming brownish in winter; base of mature leaves dark brown, persistent ..... *E. viridis*

***Ephedra nevadensis* Wats.** Nevada ephedra. Common in hills, higher parts of fans, and benchlands (where sometimes dominant) at the valley edges. Twigs remain green for several years. The current year's growth is remarkably slow to lignify and remains succulent later than is usual for most woody plants, but new growth is lacking in some years and in other years only some plants or parts of plants produce new growth. Young twigs are used by sheep in winter. Antelope use the plant year round and especially when twigs are succulent.

***Ephedra viridis* Cov.** Green ephedra. Scattered in the hills and stony places, not found on valley alluvium at the DER. Not known to be used by antelope or by sheep.

EUPHORBIACEAE; SPURGE FAMILY

Euphorbia L. Spurge; Euphorbia

Low to prostrate forbs with milky juice; leaves opposite, 3-15 mm long, more or less oblique at the base; pistillate and staminate flowers borne together in cuplike structures (involucres), the pistillate flowers solitary and central, the staminate flowers 1-several, borne at the edge of the involucre and consisting of a single stamen, pistillate and staminate flowers and involucres collectively referred to as a cyathium, the cyathium appearing as a single flower; edge of the involucre often with glands and with or without petallike appendages; fruit a 3-celled, pedicelled, usually nodding capsule.

1 Plants perennial, from little to much branched caudices; leaves entire, some broadly ovate to orbicular ..... *E. fendleri*
1 Plants annual, from simple, slender taproots; leaves minutely serrate at the apex, obovate-oblong to ovate-oblong ..... *E. serpyllifolia*

***Euphorbia fendleri* T. & G.** Fendler spurge. (*Chamaesyce fendleri* [T. & G.] Small) Occasional, mostly in hills and washes. June through September. Sought out by antelope.

***Euphorbia serpyllifolia* Pers.** Thymeleaf spurge or euphorbia. (*Chamaesyce serpyllifolia* [Pers.] Small) Occasional at least in some years, driveways, washes, and elsewhere. July through September. Sought out by antelope.

FABACEAE (LEGUMINOSAE); PEA FAMILY

Herbs (species native to DER); leaves alternate, pinnately or palmately compound, stipulate; flowers bisexual, irregular, usually in racemes or heads; calyx 5-lobed; corolla papilionaceous (sweetpea type) with 5 petals, but these appearing as 4, the uppermost one (banner) the longest, the 2 lateral ones (wings) turned about 90° to the banner, the lower 2 (keel) fused and appearing as a single boat-shaped or keel-shaped petal, this parallel to and folded between the wings; stamens 10, the filaments all united into a tube that surrounds the pistil (monodelphous), or 9 united and 1 free (diadelphous); ovary superior; fruit (pod) a legume.

1 Leaves pinnately compound
  2 Leaves odd pinnate, the rachis with a terminal leaflet; styles not bearded ..... *Astragalus*
  2 Leaves even pinnate, the rachis of at least some ending in a tendril and not a leaflet; styles bearded down one side as in a toothbrush ..... *Lathyrus*
1 Leaves trifoliate or palmately compound
  3 Plants 30-80 cm tall or taller, annual or biennial; leaves 3-foliate; leaflets serrate-dentate on the upper half; racemes few to several, not all terminal; flowers 4-6 mm long, not bluish ..... *Melilotus*
  3 Plants 3-10 (20) cm tall, perennial, or if annual then some leaves with more than 3 leaflets and leaflets entire; racemes or heads solitary and terminal; petals sometimes bluish

4 Plants annual, caulescent, greenish with scattered hairs, the hairs of the stems and petioles strongly spreading; stamens diadelphous ..... *Lupinus*
4 Plants perennial, acaulescent, whitish to grayish with dense appressed hairs; stamens monodelphous
5 Flowers borne in heads; plants pulvinate caespitose, growing on rock outcrops; pods about 5 mm long ..... *Trifolium*
5 Flowers borne in racemes, these sometimes headlike; plants caespitose or not, not restricted to rock outcrops; pods 8-25 mm long .. *Astragalus calycosus*

Astragalus L. Milkvetch; Vetch

Perennial herbs, mostly with odd-pinnate compound leaves; flowers in racemes, white, pink, or purplish; stamens diadelphous, ovary enclosed in the staminal sheath. Most species are short-lived at DER. *Astragalus calycosus* and *A. newberryi* are seen every year, but the others are rare most years and never really abundant in the years when they are common.

1 Leaves strictly basal, with 3-5 (7) leaflets; flowers 10-16.5 mm long, the wing petals notched at the apex; plants seldom over 10 cm tall; pods curved, 8-25 mm long, 3-4.5 mm thick, strigose ..... *A. calycosus*
1 Leaves not strictly basal or some usually with more than 5 leaflets or flowers 18-32 mm long; plants various; pods various but either over 4.5 mm thick or densely woolly pubescent
2 Plants green glabrous or with scattered hairs, with well-developed leafy stems, stipules shorter than and not concealing the internodes; pods glabrous or nearly so; flowers 10-21 mm long
3 Pods bladdery-inflated, the walls thin and papery; racemes mostly equaling or exceeding the leaves; stems commonly over 3 mm thick; plants rather infrequent ..... *A. lentiginosus*
3 Pods not bladdery-inflated, the walls rather thick and leathery; racemes exceeded by the leaves; stems commonly less than 3 mm thick; plants rather common around the base of Tunnel Springs Mountain ..... *A. beckwithii*
2 Plants white or gray with dense villose, or tomentose hairs, acaulescent or subacaulescent, leafy stems if present usually with stipules longer than and concealing the internodes; pods covered with dense woolly hairs; flowers 18-32 mm long
4 Racemes 7-20 flowered, the axis 1.5-18 cm long in fruit; flowers 18-25 mm long; pods bilocular, descending; leaves with 15-35 leaflets, with straight and spirally twisted hairs; plants 6-30 cm tall ..... *A. mollissimus*
4 Racemes 2-8 flowered, the axis 0.4-2.7 cm long in fruit; flowers 20-32 mm long; pods unilocular, ascending to spreading; leaflets 3-15 (19), with various pubescence; plants 2-14 cm tall
5 Plants strictly acaulescent, mostly with persistent leaf bases and stipules clothing the base of stems and caudex; leaflets 3-15, gray-green with a bluish cast; calyx 11.5-20 mm long; pods 18-23 mm long, 7-12 mm thick, villous-tomentose; plants rather common ..... *A. newberryi*
5 Plants subacaulescent, lacking persistent leaf bases and stipules; leaflets 9-19, gray-green without bluish cast; calyx 12-14 mm long; pods 17-30 mm long, 5.5-7.5 mm thick, shaggy-villose; plants rather rare ..... *A. utahensis*

***Astragalus beckwithii* T. & G. var. *purpureus* Jones** Beckwith milkvetch. Locally common on Tunnel Springs Mountain. (April) May through June.

Astragalus calycosus* Torr. in Wats. var. *calycosus Torrey milkvetch. Occasional, mostly in hills and upper parts of fans. May through June.

***Astragalus lentiginosus* Dougl. var. *araneosus* (Sheld.) Barneby** Specklepod locoweed. (*A. araneosus* Sheld.) Apparently short-lived and common in some years (but not abundant), but rare or absent in other years, on sandy to loamy areas toward the bottom of Pine Valley. May through June.

***Astragalus mollissimus* Torr. var. *thompsonae* (Wats.) Barneby** Woolly milkvetch. (*A. bigelovii* Gray) Infrequent or occasional on old fans especially south and east of Tunnel Springs Mountain. May through June.

***Astragalus newberryi* Gray** Newberry milkvetch. Occasional, mostly in hills and upper parts of fans. Late April through June.

***Astragalus utahensis* (Torr.) T. & G.** Utah locoweed, Utah milkvetch. Apparently rare, the two records seen are from Halfway Hills and Warm Cove Ridge. May through June.

Lathyrus L.
Peavine

***Lathyrus brachycalyx* Rydb.** Perennial villous herbs, 5-20 cm tall; leaves odd pinnate, the rachis ending in a tendril; leaflets 6-12, 10-25 mm long, 2-10 mm wide, linear to oblanceolate; racemes with 2-5, pink to pink-purple flowers 15-25 mm long; pods 3-7 cm long, 5-10 mm wide. A few plants seen in a small canyon on the east side of Warm Cove Ridge. May through June.

Lupinus L.
Lupine

***Lupinus pusillus* Pursh var. *intermontanus* (Heller) C. P. Smith** Annual herbs, 3-15 cm tall, with sessile cotyledons, with spreading long hairs; leaves mostly cauline; leaflets 3-9, 11-48 mm long, 2-10 mm wide, oblanceolate, flat or folded; racemes 4-several flowered; flowers 8.5-12 mm long, the petals blue or rarely pink or white. Infrequent or occasional in some years on sandy soil at the east edge of the DER in Pine Valley. May through June.

Melilotus L.
Sweetclover

Plants annual or biennial, usually 30-100 cm tall or taller, caulescent; leaves trifoliate, the leaflets serrate-dentate on the upper half; flowers 4-6 mm long, 38-115 per raceme; pods 2.5-6 mm long.

1 Petals white ..... *M. alba*
1 Petals yellow ..... *M. officinalis*

***Melilotus alba* Medicus** White sweetclover. Introduced from Europe, occasional along Highway 21 in Halfway Hills, to be expected elsewhere along roads. May through June, or September with rains.
***Melilotus officinalis* (L.) Pallus** Yellow sweetclover. Introduced from Europe, the one specimen seen is from near DER Headquarters, to be expected elsewhere along roads. May through June or September with rains.

Trifolium L.
Clover

***Trifolium andersonii* A. Gray var. *friscanum* Welsh** Dolomite clover. Perennial, pulvinate caespitose, mat-forming acaulescent herbs, 1-3 cm tall; leaflets 3-5 per leaf, 5-11 mm long, 2-5 mm wide, subvillous, pointed at tip; heads with about 3-5 flowers; calyx villous, banner about 6-9 mm long; pods about 5 mm long, villous. Locally common at a few places on Tunnel Springs Mountains, cracks of dolomite outcrops. The var. *friscanum* is a narrow endemic known only from the San Francisco Mountains and Tunnel Springs Mountain.

GENTIANACEAE; GENTIAN FAMILY

Swertia L.
Swertia; Green Gentian

***Swertia albomarginata* (Wats.) Kuntze** Whitemargined frasera, green gentian. (*Frasera albomarginata* Wats.) Perennial branched herbs, 20-40 cm tall, glabrous; leaves basal and cauline in whorls of 3-4, 2-8 cm long, lance-linear; flowers in open panicles; corolla greenish-white with dark dots, 8-10 mm long, bearing a linear gland, the gland with a fringe of hairs at the margin; fruit a capsule. Occasional in pinyon-juniper and mahogany communities on Tunnel Springs Mountain and Halfway Hills. May through June.

GERANIACEAE; GERANIUM FAMILY

Erodium L'Her.
Storksbill; Filaree

***Erodium cicutarium* (L.) L'Her.** Alfileria. Annual herbs, 3-10 cm tall, strigose and glandular-pubescent; leaves mostly 2-7 (10) cm long, pinnately compound, cut into fine segments; petals 5-7 mm long, rose-lavender; fruit a schizocarp, with a stylar column 1-5 cm long, the 5 mericarps separating at maturity, their elongate styles twisting in a corkscrew fashion, responding to changes in humidity. Introduced from the Mediterranean region, infrequent but in some years common on sheep bedgrounds that have been abandoned for several years. March through May and perhaps again from September through October with late summer or fall rains.

HYDROPHYLLACEAE; WATERLEAF FAMILY

Phacelia Juss.
Scorpionweed

Forbs pubescent and sometimes glandular; leaves alternate, toothed to pinnately lobed, basal and cauline; flowers often in coiled, secund cymes that unfold and straighten as the flowers mature; corolla united at least at base, tubular to rotate; style shortly to deeply bifid.

1 Plants (5) 10-40 cm tall, winter annual, common in some years especially in valleys and on fans; corollas 6-10 mm long, deep violet or blue-purple, with a white throat, or all white in albino forms; stamens and style exserted ..... *P. crenulata*
1 Plants 2-5 (10) cm tall, annual, rather rare in hills on DER; corollas 2-4.5 mm long, white to pale lavender, the tube yellowish; stamens and styles included
2 Leaves entire or shallowly toothed, elliptic to ovate; filaments and style hairy at the base ..... *P. incana*
2 Leaves pinnately lobed, oblong to linear in outline; stamens and style glabrous ..... *P. ivesiana*

***Phacelia crenulata* Torr. in Wats. var. *corrugata* (A. Nels.) Brand.** (*P. corrugata* A. Nels.) Infrequent or occasional, and in some moist years abundant, and one of the few forbs to give flower color to the desert aspect, but in some years lacking; mostly in valleys but also in hills. May through June.

***Phacelia incana* Brand.** Infrequent or locally common in some years, hills. April through June.

***Phacelia ivesiana* Torr. in Ives.** The only specimen seen is from Tunnel Springs Mountain, from duff of a pinyon tree. May through June.

LAMIACEAE (LABIATAE); MINT FAMILY

Perennial herbs or shrubs; leaves opposite; flowers in axillary or terminal clusters; corollas united, more or less irregular and 2-lipped; ovary superior, 4-lobed, with one 2-4 cleft style; fruit of four 1-seeded nutlets.

1 Plants woody at least toward the base; flowers blue, borne in 1-4 headlike glomerals ..... *Salvia*
1 Plants herbaceous; flowers not blue, axillary or spicate
2 Plants puberulent, strongly aromatic; leaves 5-15 mm long, 1-3 (5) mm wide, linear to narrowly elliptic, entire, sessile; stamens 2 ..... *Hedeoma*
2 Plants (at least stems and sometimes leaves) white-woolly, not strongly aromatic; leaves 15-40 mm long or longer, about as wide, ovate to suborbicular, crenate, petioled; stamens 4 ..... *Marrubium*

Hedeoma Pers. Pennyroyal

***Hedeoma drummondii* Benth.** Drummonds pennyroyal. Perennial, aromatic herbs, 10-25 cm tall, with several branched stems; corollas about 1 cm long. The few specimens seen are from the east side of Warm Cove Ridge. May through June.

Marrubium L. Horehound

***Marrubium vulgare* L.** Common horehound. Perennial or perhaps biennial nonaromatic herbs, 20-50 cm tall with 1-several stems; herbage usually gray or white with woolly hairs except on the upper leaf surfaces; corolla 5-6 mm long, whitish. Introduced from Europe, somewhat weedy but rare, mostly along roadsides and around Headquarters.

Salvia L. Sage

***Salvia dorrii* (Kell.) Abrams var. *argentea* (Rydb.) Cronq.** Grayball sage. (*S. carnosa* Dougl.) Shrubs 20-50 cm tall; stems densely scurfy-pubescent, punctate-glandular, strong aromatic; leaves 7-15 mm long, round obovate to spatulate; glomerules of flowers subtended by purplish or greenish rounded bracts; corollas 10-12 mm long, 2-lipped. Infrequent in hills and along washes. May through June.

LILIACEAE; LILY FAMILY

Perennial herbs from bulbs; leaves simple, entire, linear, with parallel veins, usually strongly sheathing; flowers regular or nearly so, bisexual; perianth of 6 tepals (the sepals and petals often alike and referred to collectively as tepals); stamens 6; ovary superior; styles 3 or stigmas 3-lobed; fruit a capsule.

1 Inflorescence an umbel with 5-many rays; tepals about 7-12 mm long, white to pinkish; plants with strong onionlike odor, 3-10 cm tall; leaves 1-2 (3) ..... *Allium*
1 Inflorescence not an umbel; tepals various; plants not with onionlike odor; leaves various
2 Flowers 10 or more in a raceme or panicle; tepals 3-6 mm long, white to cream; leaves mostly basal or basally disposed ..... *Zigadenus*
2 Flowers mostly 1-4; tepals 10-35 mm long, variously colored; leaves not basal or basally disposed

3 Petals white, tinged with pink, 2-3.5 cm long, strongly contrasting with the smaller, greenish sepals; leaves crowded, not much overlapping; capsules lanceolate, 2.5-3.5 cm long ..... *Calochortus*
3 Tepals greenish-brown to chocolate-brown and spotted, all about equal and not strongly differentiated into petals and sepals; leaves sometimes crowded and strongly overlapping; capsules broadly obovoid, 1-1.5 cm long ..... *Fritillaria*

Allium L. Onion

With features of the family and as listed in the key.

1 Leaves l, terete, often coiled at the tip; stems terete; umbels with few to many flowers; pedicels up to twice as long as the tepals ..... *A. nevadense*
1 Leaves 2, flattened, often curved; stems somewhat flattened, slightly winged; umbels 5-15 flowers; pedicels only about as long as the tepals ..... *A. parvum*

***Allium nevadense* Wats.** Nevada onion. The two specimens seen are from Halfway Summit. May through June.

***Allium parvum* Kellogg** Small onion. The two specimens seen are from Tunnel Springs Mountain.

Calochortus Pursh Sego Lily; Mariposa Lily

***Calochortus flexuosus* Wats.** Weakstem or flexstem sego lily. Perennial herbs, more or less decumbent or twining among bushes or straggling along the ground; stems 15-30 (40) cm long; leaves scattered; flowers 1-4, showy. Infrequent in hills. May through June.

Fritillaria L. Fritillary

***Fritillaria atropurpurea* Nutt.** Perennial herbs, with erect stems, 10-40 cm tall; leaves rather crowded to scattered on the upper half of the stem; flowers 1 (2-4), nodding; capsules erect, slightly winged. The one specimen seen is from the northern boundary of the DER on Tunnel Springs Mountain.

Zigadenus Michx. Deathcamas

***Zigadenus paniculatus* Wats.** Foothill deathcamas. Perennial herbs from bulbs covered with dark blackish scales, 20-40 cm tall; leaves 10-20 cm long, 3-15 mm wide, basal or on the lower fourth of the stem, upper leaves reduced and bractlike; inflorescence showy but petals small; fruit a 10-18 mm long capsule. Rare, upper parts of fans and hills. May through June.

LINACEAE; FLAX FAMILY

Linum L. Flax

Perennial herbs, glabrous or nearly so, glaucous; leaves simple, alternate, entire, linear or nearly so, sessile, 1-3 cm long, 1-4 mm wide; flowers more or less showy; sepals and petals 5, separate, the sepals persistent, the petals opening in morning, deciduous within a few hours (usually by noon); fruit a 10-chambered capsule, each chamber 1-seeded.

1 Petals blue; stigmas elongate or at least longer than wide ..... *L. perenne*
1 Petals yellow; stigmas capitate ..... *L. subteres*

***Linum perenne* L. var. *lewisii* (Pursh) Eaton & Wright** Blue flax. Occasional on upper parts of fans and in hills. May through June. Used by antelope.

***Linum subteres* (Trel.) Winkler in Engler & Prantl.** Yellow flax. (*L. aristatum* Engelm. in Wisliz. var. *subteres* Trel.) The one specimen seen (Hart sn BRY) is from fans or benchlands west of Tunnel Springs Mountain.

LOASACEAE; LOASA FAMILY

Mentzelia L. Blazingstar; Mentzelia; Stickleaf

Annual, biennial, or short-lived perennial plants; stems often glossy white, the epidermis exfoliating; leaves alternate, simple, covered with minute many-barbed hairs; flower terminal or axillary, small to showy; stamens 10-many; fruit a capsule.

1 Petals 2-6 mm long, 5, not apparently 10, the filaments of stamens all filiform; capsules about 2-3 mm thick, 5-30 mm long; plants winter annual, with slender (2-4 mm thick) stems ..... *M. albicaulis*
1 Petals 25-80 mm long, 5, and apparently 10 with 5 of the outer filaments expanded and petaloid; capsules 15-35 mm long, about 1 cm thick; plants biennial, robust, 30-100 cm tall, with thick (10-15 mm or more) stems; leaves to 15 cm long ..... *M. laevicaulis*

***Mentzelia albicaulis* Dougl. in Hook.** Common winter annual in most years, mostly in sandy areas of rodent disturbance in valleys and in swales near washes. April through June.

***Mentzelia laevicaulis* (Dougl.) T. & G.** Blazingstar. Occasional at least in some years, along Highway 21 through Halfway Hills. June through July or perhaps to September with summer rains.

MALVACEAE; MALLOW FAMILY

Sphaeralcea St. Hil. Globemallow

Perennial herbs, with sparse to dense stellate pubescence; leaves toothed to palmately lobed to dissected; petals 5, orange; stamens numerous, united by their filaments; fruit a schizocarp with 8-20 carpels, the carpels separating at maturity.

1 Leaf blades irregularly crenate-dentate to slightly 3-5 lobed; plants seldom more than 15 cm tall, white to gray with dense pubescence, long-lived perennial ..... *S. caespitosa*

1 Leaf blades 3-5 lobed to divided, the main divisions usually cleft, parted or toothed; plants (10) 15-50 cm tall, gray-green with dense pubescence or thinly pubescent and greenish, short-lived perennial (probably not more than 5 years) ..... *S. grossulariifolia*

***Sphaeralcea caespitosa* Jones** Tufted globemallow. Common, but not abundant, on shallow stony-gravelly soils in hills and upper parts of old fans. May through June.

***Sphaeralcea grossulariifolia* (H. & A.) Rydb.** Gooseberryleaf globemallow. Common but scattered in many plant communities of valley bottoms where it is the most widespread perennial forb and in many places the only one. Regularly May through June and (with sufficient precipitation) any time until autumn frost. Stems remain green into early winter in some years and are then used by sheep; resumes growth in early spring and in some years grazed by sheep before they leave the winter range. Used by antelope during the growing period.

NYCTAGINACEAE; FOUR-O'CLOCK FAMILY

Perennial herbs (on DER), glabrous, puberulent, short-villose or glandular, often glaucous; leaves simple, opposite or all basal, entire, the blades elliptic, ovate to deltoid; flowers regular, bisexual, subtended by an involucre of free or united calyxlike bracts; perianth of a single whorl, corollalike, united, 3-5 lobed; fruit an achene, usually angled or ribbed.

1 Flowers many (more than 5) in terminal or axillary heads; perianth white or pinkish, the limb 2-8 mm wide, the tube narrow (salverform), 15-20 mm long; stamens included; involucral bracts free, scarious; petioles 10-50 mm long ..... *Abronia*

1 Flowers solitary or to 5 in clusters; perianth purplish-red, the limb 8-30 mm wide, the tube broader (campanulate to funnelform), 8-20 mm long; stamens usually more or less exserted; involucral bracts not scarious; petioles various
  2 Stems and sometimes leaves puberulent to short-pilose and sometimes glandular; involucres united, glandular; perianth 8-12 mm long; petioles 5-20 mm long ..... *Oxybaphus*
  2 Plants glabrous or obscurely puberulent upward; involucre bracts free, glabrous; perianth 20-25 mm long; petioles 1-10 mm long ..... *Hermidium*

Abronia Juss. Sandverbena

With features of the family and as listed in the key.

1 Leaves opposite, borne well upward on the stems; plants not at all caespitose ..... *A. elliptica*

1 Leaves basal or nearly so; plants somewhat caespitose ..... *A. nana*

***Abronia elliptica* A. Nels.** Pink sandverbena. Occasional on sandy soil in Pine Valley near the east boundary of DER. May through June.

***Abronia nana* Wats.** Dwarf sandverbena. Occasional, mostly on upper fans and hills. April through June.

Hermidium Wats.

***Hermidium alipes* Wats.** (*Mirabilis alipes* [Wats.] Pilz.) Perennial herbs, 15-30 cm tall; leaf blades 2-7 cm long, ovate or nearly so; perianth 2-2.5 cm long; stamens 5-7. Occasional, valleys, fans, and lower hills. May through June. Used by antelope when green, dries up by midsummer, the stems becoming detached at or just below ground level, and blowing away with the leaves still attached.

Oxybaphus L'Her. ex Willd. Umbrellawort

***Oxybaphus pumilus* Standl.** (*Allionia pumila* Standl.) Infrequent in gravelly wash bottoms and dry hills. May through June.

ONAGRACEAE; EVENING PRIMROSE FAMILY

Annual or perennial herbs (on DER); leaves alternate or basal, simple to pinnatifid; flowers bisexual, regular; sepals and petals 4, arising with 8 stamens from a floral tube; fruit a capsule.

1 Plants annual; petals 4-9 mm long; floral tube 4-8 mm long; capsules various . . . . *Camissonia*

1 Plants perennial; petals 13-50 mm long; floral tube 2.5-5 cm long or longer; capsules sessile or nearly so
  2 Leaves alternate on short stems and sometimes appearing basal, 5-15 mm long, 2-4 mm wide, entire; petals yellow, reddish-brown or orange in age; stigmas capitate . . . . *Calylophus*
  2 Leaves basal, or if cauline then not entire and over 15 mm long; petals white or pink; stigmas divided into 4 linear lobes . . . . *Oenothera*

Calylophus Spach.

***Calylophus lavandulaefolius* (T. & G.) Raven** Lavenderleaf evening primrose. (*Oenothera lavandulaefolia* T. & G.; *Galpinsia lavandulaefolia* [T. & G.] Small) Plants small, suffrutescent, caespitose, grayish strigose; flowers solitary in upper axils; petals 13-22 mm long. Occasional in hills, shallow soils over dolomite bedrock, and cracks of exposed bedrock. May through August.

Camissonia Link Camissonia

Annual herbs (at DER); flowers usually opening near sunrise, sometimes in afternoon, withering in less than a day; petals yellow, whitish, or pinkish, drying reddish or purplish; stigmas capitate.

1 Capsules sessile or nearly so, more or less contorted; petals white to pink when fresh; stems leafy; leaves entire or inconspicuously dentate; hypanthium 4-7 mm long . . . . *C. boothii*

1 Capsules on 5-20 mm long, slender pedicels, straight; petals various; stems sparsely leafy to subscapose; leaves serrate to pinnate; hypanthium 0.5-4 mm long
  2 Petals white or cream to pinkish; stigmas exserted beyond the anthers at anthesis; capsules 1.5-2.3 mm thick; leaves mottled with brownish purple spots . . . . *C. claviformis*
  2 Petals yellow, same color as stamens; stigmas surrounded by anthers, not exserted at anthesis; capsules 1.2-1.8 mm thick . . . . *C. walkeri*

***Camissonia boothii* (Dougl.) Raven ssp. *alyssoides* (H. & A.) Raven** Alyssum evening primrose. (*Oenothera alyssoides* H. & A.; *Sphaerostigma alyssoides* [H. & A.] Walp.) Occasional to locally common, hills, fans, and valleys, mostly in gravelly washes where abundant in some years. May through June and responding to adequate rainstorms through September.

***Camissonia claviformis* (Torr. & Frem.) Raven ssp. *integrior* (Raven) Raven** Brown-eyed evening primrose. (*Oenothera clavaeformis* Torr. & Frem.; *Chylismia clavaeformis* [Torr.] Heller) Occasional in valleys (perhaps only Pine Valley). May through June. Plants from the DER have been confused with *Camissonia scapoidea* (T. & G.) Raven. Plants of *C. scapoidea* have yellow and mostly smaller petals and stigmas that are surrounded by the anthers, and they have mostly simple leaves.

***Camissonia walkeri* (A. Nels.) Raven ssp. *tortilis* (Jeps.) Raven** (*Oenothera walkeri* [A. Nels.] Raven) One specimen (Welsh and others 13317a BRY) appears to belong to this taxon. The specimen is from Sevy dolomite on benchland between Pine Valley and the pass between Tunnel Springs Mountain and Warm Cove Ridge. May through June.

Oenothera Evening Primrose

With features of the family and as listed in the key.

1 Leaves all from a basal tuft, entire or wavy-margined; petals 2.5-4 cm long; floral tube over 3 cm long; plants from a taproot . . . . *O. caespitosa*

1 Leaves borne on the stems, basal ones lacking or few, pinnatifid or at least cleft; petals about 1-2 cm long; floral tube 1.5-3 cm long; plants from rhizomes, sometimes forming patches . . . . *O. pallida*

***Oenothera caespitosa* Nutt. var. *crinita* (Rydb.) Munz** Tufted evening primrose. (*Pachylophus crinitus* Rydb.) Occasional, widespread. Late April through June, or through September with precipitation. Grazed by antelope whenever green and growing.

***Oenothera pallida* Lindl.** Pale evening primrose. (*Anogra pallida* [Lindl.] Britton) Occasional on sandy soil at east edge of DER in Pine Valley.

OROBANCHACEAE; BROOMRAPE FAMILY

***Orobanche* L.**
Broomrape; Cancer-root

Perennial herbs (on DER), parasitic on roots of sagebrush, galleta, and other plants, lacking chlorophyll, whitish, yellowish, to brown, often fleshy; herbage glandular-hairy; leaves alternate, bractlike; corollas united, 2-lipped, the lips lobed; stamens 4; fruit a capsule.

1 Flowers sessile or on pedicels to about 2 cm long, closely subtended by 2 bractlets ..... *O. corymbosa*
1 Flowers on scapelike pedicels about as long as the stems, not closely subtended by 2 bractlets ..... *O. fasciculata*

***Orobanche corymbosa* (Rydb.) Ferris** Infrequent or perhaps occasional, widespread. June through July.

***Orobanche fasciculata* Nutt.** Clustered broomrape. Infrequent but widespread. June through July.

PAPAVERACEAE; POPPY FAMILY

***Argemone* L.**
Prickly Poppy

***Argemone munita* Dur. & Hilg.** Prickly poppy, cowboy eggs. (*A. hispida* Gray misapplied) Annual, prickly, coarse herbs, 60-100 cm tall; leaves alternate, pinnately lobed; flowers 5-10 cm in diameter; petals white; stamens numerous, yellow; stigmas 3-7 lobed; fruit a capsule, 35-55 mm long. Occasional in some years, road shoulders, raw banks of washes, and other areas of disturbance. July through September with summer rain.

PINACEAE; PINE FAMILY

***Pinus* L.** **Pine**

***Pinus monophylla* Torr. & Frem. in Frem.** Singleleaf pinyon. Small trees to about 6 (10) m tall; leaves needlelike, stout, sharp-pointed, (2) 3-5 (6) cm long; seeds borne in cones, the cones 3.5-6 (8) cm long, the seeds 13-15 (17) mm long. Occasional to dominant or codominant with juniper on Tunnel Springs Mountain.

POACEAE (GRAMINEAE); GRASS FAMILY

Annual or perennial herbaceous plants; stems mostly terete, the internodes mostly hollow, the nodes swollen and prominent, mostly not hollow; leaves alternate, simple, parallel-veined, strongly sheathing, the blades linear or filiform; ventral surface of the collar (junction of sheath and blade) projected into a ligule, this a membranous scale or a fringe of hairs; flowers bisexual or unisexual, solitary or 2-many in a spikelet, spikelets consisting of a rachilla (axis), 2 glumes (empty scales that subtend or envelope 1 or more florets), and 1 or more florets; florets consisting of: (1) 2 scales (a lemma and a palea, the lemma usually enclosing the palea), (2) usually 3 stamens, (3) a caryopsis (seed) from a 1-ovuled pistil with 2 styles and plumose stigmas.

1 Plants not restricted to or near irrigated places at Headquarters
  2 Ligule of a fringe of hairs; plants 3-20 (30) cm tall, sometimes more or less matted; inflorescence congested; awn of lemmas lacking or to 5 mm long
    3 Inflorescence of 1-3 one-sided (comblike) spikes; stem leaves few (1-3), not closely subtending nor fascicled in the inflorescence ..... *Bouteloua*
    3 Inflorescence not of one-sided comblike spikes, sometimes closely subtended by or in a fascicle of leaves
      4 Lemmas each with 9 plumose awns, the awns 2-4.5 mm long; inflorescence a grayish-green dense spikelike panicle, usually closely subtended or partly enveloped at the base by the upper leaf-sheath; stems erect ..... *Enneapogon*
      4 Lemmas awn tipped or with only 1-3 awns

5 Inflorescence closely subtended by or partly hidden by 2-several or a fascicle of leaves, these leaves usually exceeding the inflorescence; lemmas bifid or deeply lobed; plants 3-15 cm tall

6 Plants not stoloniferous, strongly perennial; inflorescence subtended by but not hidden among 1-3 leaves that are rather abruptly narrowed at the collar, the blades long-acuminate; some of the lemmas deeply 2-3 lobed, the lobes awned from the tip, some of the awns sparsely plumose ..... *Blepharidachne*

6 Plants sometimes stoloniferous, annuals or short-lived perennials; inflorescence in a fascicle of leaves, sometimes partly hidden among the leaves; lemmas not deeply lobed, or if so awned from the back between the lobes, the awns not plumose

7 Spikelets nearly concealed in the fascicle of leaves; glumes not extending beyond midlength of the lower 2 lemmas; lemmas sparsely pubescent toward the base; bifid and awn tipped at the apex; plants annual ..... *Munroa*

7 Spikelets more or less visible in the fascicle of leaves; glumes as long or longer than the lower 2 lemmas; lemmas densely pilose pubescent, lobed to the middle or lower, awned from the base of the lobe, the awn equally or scarcely exceeding the lobes ..... *Erioneuron pulchellum*

5 Inflorescence not closely subtended by nor enveloped in a fascicle of leaves

8 Ligule ciliate-fringed and membranous below, apparently but not actually of a fringe of hairs; inflorescence a spike; spikelets with a tuft of long pilose hairs at the base, soon falling and leaving a bare zigzagged rachis; plants 15-45 cm tall, from robust scaly rhizomes . *Hilaria*

8 Ligule of a fringe of hairs; inflorescence headlike or ramose; spikelets without tufts of hair at the base, although the backs of the lemmas densely hairy, at least the glumes persisting; plants tufted not rhizomatous, 5-15 cm tall ..... *Erioneuron pilosum*

2 Ligules membranous and not of a fringe of hairs or else plants mostly over 30 cm tall or awns of lemmas over 9 mm long

9 Lemmas 3-awned, the awns 1-3 cm long or longer; ligules of a fringe of hairs ..... *Aristida*

9 Lemmas awnless or awns solitary or less than 1 cm long; ligules membranous except in *Sporobolus*

10 Ligules of a fringe of hairs; glumes 1-3 mm long, awnless; lemmas only slightly longer than the glumes, awnless; spikelets 1-flowered; inflorescence an open or contracted panicle, sometimes enclosed in the upper leaf-sheath ..... *Sporobolus*

10 Ligules membranous, not of hairs but sometimes with ciliate hairs near to and easily confused with the hairs of the collar; glumes over 3 mm long or lemmas awned or spikelets more than 1-flowered, or all three

11 Inflorescence a spike; spikelets all sessile and more than 1-flowered except in *Hordeum*

12 Glumes as well as the lemmas awned, the awn over 1 cm long; rachis breaking up (disarticulating) at maturity

13 Spikelets 1 per node of the rachis; glumes constricted to an awn, not awnlike their entire length; plants rare, sterile hybrids of *Agropyron* and *Sitanion* ..... *Agrositanion*

13 Spikelets 2 or 3 per node of the rachis; glumes awnlike their entire length; plants common or restricted, not sterile

14 Plants rare, known from around Pine Valley Playa; spikelets 3 per node of the rachis, the 2 lateral spikelets slightly pedicellate, empty, sometimes reduced to awns; central spikelet sessile, fertile, with 1 floret ..... *Hordeum*

14 Plants widespread, scattered to common in hills, fans, and valleys; spikelets 2 per node of the rachis, both alike, with 1-6 florets ..... *Sitanion*

12 Glumes not awned or the awns less than 6 mm long; lemmas awnless or awns less than 6 mm long except in *Agropyron spicatum*; rachis not breaking apart at maturity

15 Spikelets each with a tuft of pilose hairs (these 3-6 mm long) at the point of attachment to the rachis, soon falling (disarticulating below the glumes) and leaving a bare zigzagged rachis; ligule a ciliate-fringed membrane; plants with robust scaly rhizomes, common ..... *Hilaria*

15 Spikelets without tufts of hairs at the base, at least the glumes persistent; ligules various; rhizomes lacking except in *Agropyron smithii* and then plants rare

16 Most of the nodes of the rachis with 2 or more spikelets; glumes narrow and more or less awnlike their entire length; lemmas awnless or awn tipped; plants without rhizomes ..... *Elymus*

16 Spikelets 1 per node of the rachis, occasionally 2 at some of the lower nodes, and plants rhizomatous; glumes not awnlike their entire length or somewhat so in *Agropyron smithii*, but then plants rhizomatous; lemmas sometimes with awns over 1 cm long ..... *Agropyron*

11 Inflorescence an open or contracted panicle, if contracted then the branches evident upon teasing the inflorescence apart; spikelets with 1-several florets

17 Spikelets with 1 floret, the lemma awned; plants perennial

18 Glumes shorter than the lemma; scabrous on the keel toward the tip; stems decumbent, branched at the base, appearing rhizomatous ..... *Muhlenbergia*

18 Glumes longer than the lemmas, not scabrous on the keel; stems ascending to erect not decumbent, tufted, not branched, not appearing rhizomatous

19 Awns of lemmas 2-8 (10) mm long, rather quickly deciduous; glumes 3-8 mm long; inflorescence open, at least the lower branches widely spreading ..... *Oryzopsis*

19 Awns of lemmas 13-100 mm long or longer; glumes 7-25 (35) mm long; inflorescence open or contracted ..... *Stipa*

17 Spikelets with 3-several florets; lemmas awnless and plants perennial or lemmas awned and plants annual

20 Lemmas awnless; spikelets 3-8 (10) mm long; plants perennial ..... *Poa*

20 Lemmas awned; spikelets various; plants annual

21 Awns of lemmas (7) 10-17 mm long; spikelets (12) 15-20 (24) mm long; leaf sheaths often densely pubescent ..... *Bromus*

21 Awns of lemmas 1.5-5 mm long; spikelets 5-10 mm long ..... *Festuca*

1 Plants restricted to Headquarters area

22 Ligule a fringe of hairs, less than 1 mm long; plants unisexual, from robust scaly rhizomes, in lawns and roadsides near lawns; spikelets several-flowered 10-25 mm long; lemmas awnless, (inland saltgrass) ..... *Distichlis spicata* (L.) Greene var. *stricta* (Torr.) Scribn.

22 Ligule membranous, not a fringe of hairs, 0.5-8 mm long; plants bisexual, caespitose to rhizomatous; spikelets various; lemmas various

23 Inflorescence a spike; auricle (appendage that arises at either side of the ventral summit of the sheath and more or less clasp the stem) more or less developed; ligules 0.5-1 mm long; plants mostly not growing in lawns

24 Spikelets 1 per node of the rachis, or occasionaly 2 at some of the lower nodes and then plants with long-creeping rhizomes, scattered or if dense then forming a flattened spike ..... *Agropyron*

24 Spikelets 2 per node of the rachis, dense and forming a nearly cylindrical spike; plants not rhizomatous ..... *Elymus*

23 Inflorescence a panicle; auricles mostly lacking or small; ligules various; plants mostly growing in lawns

25 Spikelets 3-6 mm long, lemmas awnless; leaf blades 1-4 mm wide, folded to strongly keeled, prowlike at the tip as in the bow of a boat ..... *Poa*

25 Spikelets over 6 mm long or else lemmas awn tipped; leaf blades 4-10 mm wide, at least those of the stem flat

26 Spikelets 15-25 mm long; lemmas awnless not ciliate on margins or keel; ligules 0.5-1.5 mm long; leaves mostly all flat (smooth brome) . . . . *Bromus inermis* Leyss.

26 Spikelets 5-8 mm long; lemmas awn tipped, stiff ciliate on the keel and margins; ligules 4-8 mm long; stem leaves flat, those of the innovations strongly folded (orchardgrass) . . . . *Dactylis glomerata* L.

Agropyron Gaertn. Wheatgrass

Perennial plants; auricles (clasping appendages at the collar) often well developed; inflorescence a spike; spikelets 1 per node, occasionally 2 at some of the lower nodes of the rachis, with 3-several florets.

1 Spikelets densely crowded, 3-4 times as long as the internodes of the rachis, widely spreading and not appressed to the rachis; glumes and lemmas awn-pointed; plants introduced, uncommon on the station, mostly along roads, not rhizomatous . . . . *A. cristatum*

1 Spikelets not densely crowded, mostly less than 2 times as long as the internodes of the rachis

2 Plants rhizomatous, uncommon, known only from around Headquarters; glumes narrow, tapered from near the base, nearly subulate awnlike; lemmas awn tipped, the awn not over 2 mm long . . . . *A. smithii*

2 Plants not rhizomatous, common in hills; glumes more or less elliptic, not awnlike; lemmas usually with awns 1-1.5 (2) cm long . . . . *A. spicatum*

***Agropyron cristatum* (L.) Gaertn.** Crested wheatgrass. Introduced from Eurasia, rare, found at Headquarters area and along roadsides.

***Agropyron smithii* Rydb.** Western wheatgrass. (*Elytrigia smithii* [Rydb.] Love; *Pascopyrum smithii* [Rydb.] Love) Known from a single patch at Headquarters where it was planted.

***Agropyron spicatum* (Pursh) Scribn. & Sm.** Bluebunch wheatgrass. (*Elytrigia spicata* [Pursh] D. R. Dewey) Occasional to common, apparently confined to Tunnel Springs Mountain, mostly in the pinyon-juniper zone. May through June. The foliage sometimes greens up in the fall.

X *Agrositanion* Bowden

X *Agrositanion saxicola* (Scribn. & Sm.) Bowden (*Agropyron saxicola* [Scribn. & Smith] Piper) Squirreltail wheatgrass. A hybrid involving *Agropyron spicatum* and *Sitanion hystrix*. The only record seen is from the bank of a wash at Bullgrass Knoll.

Aristida L. Three-awn

***Aristida purpurea* Nutt.** Purple three-awn. (*A. fendleriana* Steud.; *A. longiseta* Steud.) Perennial plants, tufted, 15-30 cm tall, leaf blades mostly basal, curling, pilose on the collar; ligules less than 1 mm long; panicles 2-6 cm long, narrow; spikelets with 1 floret; first glume about 8 mm long, the second glume about twice as long, both awnless; lemmas 9-12 mm long, each with 3 awns, the awns 2-5 cm long, divergent. Infrequent but sometimes locally common in small isolated patches, valleys, and hills. May through September with precipitation. Seldom starts growth before May, not grazed in winter by cows, sheep, or horses. Plants native to the DER have awns 1-3 cm long and are referable to var. *glauca* (Nees) A. Holmgren & N. Holmgren. Plants with awns mostly 3-10 cm long are advancing from the east along Highway 21 in Pine Valley. The long-awned plants are referable to var. *longiseta* (Steud.) Vasey.

Blepharidachne Hackel

***Blepharidachne kingii* (Wats.) Hackel** King desertgrass. Low tufted perennials, 3-8 cm tall; leaves crowded, 7-30 mm long, sharp-pointed; panicles compact, subcapitate, 1-2.5 cm long, usually subtended and exceeded by 1-2 spathelike leaves; spikelets few, 4-flowered, but only the third one fertile, the fourth reduced to 3-awned rudiment; glumes about equal; lemmas 3-lobed or short awned, the short awns more or less plumose. Occasional, upper parts of fans and lower hills. May through June, or through September with precipitation.

Bouteloua Lag. Grama Grass

Annual or perennial plants; ligules of a fringe of hairs; spikelets borne in comblike spikes, in 2 rows on 2 sides of a 3-angled rachis, with 1 bisexual and 1-3 staminate or rudimentary florets above the fertile one.

1 Plants annual, from a few fibrous roots, usually but not always on disturbed ground; spikes 1-2.5 cm long ..... *B. barbata*
1 Plants perennial, rhizomatous and more or less mat-forming, common in indigenous plant communities; spikes 1.7-4 cm long ..... *B. gracilis*

***Bouteloua barbata* Lag.** Sixweeks grama. Seen only in occasional years when sometimes locally common in a few places, mostly where the ground has been disturbed. July through September. Germinates and grows with summer rains.

***Bouteloua gracilis* (H. B. K.) Lag. ex Steud.** Blue grama, curly grass. Abundant in gravelly-loamy swales on the higher parts of fans. Late June through September. Usually starts growth about late April or later, fails to flower in some dry years, flowers up to 4 times in other years depending on timing and amount of summer and early fall precipitation.

Bromus L. Brome; Chess

***Bromus tectorum* L.** Cheatgrass. Annuals, mostly 3-25 cm tall on DER, pubescent with rather soft long hairs; ligules 1-3 mm long; leaf blades 2-4 (7) mm wide; panicle nodding, with few to many spikelets; spikelets with 3-6 florets, 12-20 mm long; first glume 5-7 mm long, second glume 8-11 mm long; lemmas 10-15 mm long, with awns 7-15 mm long. Introduced from Europe, widespread but mostly along roads and in other areas of disturbance and especially in years preceded by moister than average autumns, mostly in higher parts of valleys and lower hills, seldom seen in valley bottoms, not seen in every year.

Elymus L. Wildrye

Perennial plants with densely tufted stems (on DER); auricles usually present; inflorescence a terminal, mostly solitary spike; spikelets about 3-8 flowered; glumes narrow, mostly shorter than the lemmas; lemmas awnless or awn tipped.

1 Plants 80-150 cm tall, known from along Mountain Home Wash; leaf blades mostly flat and 4.5-15 mm wide; ligules (1) 2-7 mm long; spikelets (2) 3-6 per node of the rachis; glumes 7-15 mm long; spikes dense, 7-12 mm wide ..... *E. cinereus*
1 Plants 30-80 cm tall; leaf blades flat or rolled, 1.5-5 mm wide; ligules 0.2-1 mm long; spikelets 1-2 per node; glumes 0.8-8 (10) mm long; spikes various
  2 Plants introduced, rare, known from near Headquarters; spikelets mostly with 2-3 florets, mostly 2 per node of the rachis, 7-10 mm long; spikes dense, 4-10 mm wide, the rachis disarticulating in age ..... *E. junceus*
  2 Plants native, common on Tunnel Springs Mountain; spikelets with 3-5 (10) florets, 1 or 2 per node of the rachis, 8-18 mm long; spikes interrupted or dense, 2-5 (6) mm wide, the rachis not disarticulating ..... *E. ambiguus*

***Elymus ambiguus* Vasey & Scribn. var. *salmonis* C. L. Hitchc.** Bullgrass. (*Leymus salinae* [Jones] Love ssp. *salmonis* [C. L. Hitchc.] R. J. Atkins) Locally common on and near Tunnel Springs Mountain. May through June. Used lightly by sheep in most winters.

***Elymus cinereus* Scribn. & Merr.** Great Basin wildrye, basin wildrye. (*Leymus cinereus* [Scribn. & Merr.] Love) Occasional along Mountain Home Wash from the west boundary of DER through the Red Hills.

***Elymus junceus* Fisch.** Russian wildrye. (*Psathyrostachys juncea* [Fisch.] Nevski) Introduced from the U.S.S.R., used in rangeland seedings; the only DER specimen seen is from Headquarters.

Enneapogon Desvaux ex Beauv.

***Enneapogon desvauxii* Beauv.** Spike pappusgrass. (*Pappophorum wrightii* Wats.) Tufted perennial or perhaps sometimes annual, 10-30 cm tall, pilose to villous on culms and leaves and especially on nodes; ligules 0.7-1 mm long; blades 3-12 cm long, 1.5-2 mm wide, loosely involute; panicles 2-7 cm long, dense and spikelike; spikelets 3-flowered, the lower floret fertile, the upper 2 sterile; glumes about 3-6 mm long; lemmas 1.5-2.5 mm long, 9 nerved, the nerves extending into plumose awns, the awns 2-4.5 mm long. The one specimen seen is from Warm Cove Ridge. August through September.

Erioneuron Nash

Tufted (annuals?) perennials; leaves mostly in a basal tuft; spikelets in spikelike racemes of panicles with 4-several florets.

1 Plants more or less stoloniferous, short-lived perennial (annual?), spreading, the stems not erect; leaves basal and fascicled in the inflorescence; lemmas deeply lobed, short-awned from between the lobes ..... *E. pulchellum*

1 Plants not stoloniferous, strongly perennial; the culms erect; leaves all or nearly all basal, inflorescence elevated well above the leaves; lemmas slightly retuse at the apex, short-awned from the apex ..... *E. pilosum*

***Erioneuron pilosum* (Buckl.) Nash** Hairy tridens. (*Tridens pilosus* [Buckl.] A. S. Hitchc.; *Triodia pilosa* [Buckl.] Merr.) Occasional, fans and hills. April through September, responding to sufficient precipitation throughout the growing season.

***Erioneuron pulchellum* (H. B. K.) Tateoka** Fluffgrass. (*Tridens pulchellus* [H. B. K.] A. S. Hitchc.; *Triodia pulchella* H. B. K.) Not seen in some years, abundant in some past years on gentle slopes between Pine Valley and south face of Tunnel Springs Mountain; occasional elsewhere, mostly in hills and upper parts of fans. April through September, responding to sufficient precipitation throughout the growing season.

Festuca L. Fescue

***Festuca octoflora* Walt.** Sixweeks fescue. (*Vulpia octoflora* [Walt.] Britt.) Annuals, 3-15 (20) cm tall; ligules 0.2-0.7 mm long; blades involute; panicles 1-5 cm long, racemose or spikelike; spikelets with 6-12 florets; glumes 2-6 mm long; lemmas 3-5 mm long, with 1.5-4 mm long awns. Infrequent or locally common, mostly on hills and upper parts of fans. May through June.

Hilaria H. B. K. Galleta

***Hilaria jamesii* (Torr.) Benth.** Galleta, curly grass. Perennial plants from large scaly rhizomes, 15-30 (40) cm tall; stems with solid internodes, the nodes often pubescent; leaves mostly toward the base of stems, blade soon involute, basal leaves often recurved or curled when dry; collars usually pilose; ligules 2-3 mm long; spikelets borne in solitary, terminal spikes, on a zigzagged rachis, deciduous at maturity and leaving the rachis bare; glumes and lemmas with short awns. Dominant or codominant over much of the DER, especially on older gravelly alluvium and some sandy flats below the level of the Pleistocene lake, widespread through the hills. A useful forage species for cattle and sheep in winter. A warm-season grower, never green before the sheep leave the range in April, grows with sufficient moisture any time from May through September. The foliage dries and plants go into dormancy when the moisture is gone. The plants go through as many as 4 growth-dormancy cycles in some years.

Hordeum L. Barley; Foxtail

***Hordeum jubatum* L.** Foxtail barley. Tufted perennials sometimes short-lived; ligules 0.5-1 mm long; blades flat to involute, 1.5-4 mm wide; auricles usually lacking; spikelets in dense spikes, 3 at each node of the rachis, each 1-flowered, the central spikelet sessile with a well-developed fertile floret, the 2 lateral spikelets short-pediceled with staminate or rudimentary florets; glumes awnlike their entire length, lemmas long-awned; awns of glumes and lemmas 1-10 cm long. The only specimens seen are from the edges of the Pine Valley Playa.

Muhlenbergia Schreber Muhly

***Muhlenbergia arsenei* A. S. Hitchc.** Navajo muhly. Perennials with much branched solid stems, the stems erect or decumbent and appearing rhizomatous, wiry; leaves crowded toward the base of the stems; ligules about 1-2 mm long; blades filiform-involute, sharp pointed; spikelets in narrow panicles, with 1 floret; glumes 2-3 mm long; lemmas (3) 4-5 mm long, with a 5-12 mm long flexuous awn. Infrequent, rocky slopes of Warm Cove Ridge. August through September.

Munroa Torr.

***Munroa squarrosa* (Nutt.) Torr.** False buffalograss. Low sprawling annuals, 3-10 cm tall rarely taller; stems often stolonlike, leafless except with tufts of leaves toward the ends; the tufts of leaves subtending or partly concealing the inflorescence; leaf sheaths ciliate near the collar; ligules not over 1 mm long; blades rolled, 1-3 cm long, not over 3 mm wide; spikelets 2-4 in a usually partly concealed congested panicle, 6-8 mm long, with 3-5 florets; glumes 3-4 mm long; lemmas 3-5 mm long, 3-nerved, the midnerve prolonged into a 0.5-2 mm long awn. Occasional in years with summer rains, sometimes locally common on ground disturbed by rodents or along banks of washes. July through September.

Oryzopsis Michx. Ricegrass

Perennial bunchgrasses, leaves usually rolled; spikelets in panicles, with 1 floret; glumes equal or a little longer than the lemma; lemmas often plump, rather firm, the callus usually bearded, awned from the tip, the awn straight or bent, readily deciduous.

1 Plants common to abundant, widespread; panicles open, dichotomously branched; the primary and secondary branches often strongly divaricate; spikelets 6-8 mm long excluding the awn; lemmas with hairs about equal or longer than the body; ligules 3-8 mm long ..... *O. hymenoides*
1 Plants rare on Tunnel Springs Mountain; panicles narrow or with spreading to deflexed primary branches, the secondary branches not much if at all divaricate; spikelets 2-4 mm long excluding the awn; lemmas glabrous; ligules 0.2-2 mm long ..... *O. micrantha*

***Oryzopsis hymenoides* (R. & S.) Ricker in Piper** Indian ricegrass. Common to abundant from valley bottoms to mountains in a number of plant communities, especially common on sandy soils. May through June. Grows mostly in spring and early summer with some greening up in early autumn in some years. Palatable forage plant for cattle, sheep, and horses at all seasons, and for antelope for a few weeks after growth starts in early spring.

***Oryzopsis micrantha* (Trin. & Rupr.) Thurb.** Littleseed ricegrass. Rare, Tunnel Springs Mountain, pinyon-juniper communities on shady sides of rock outcrops.

Poa L. Bluegrass

Perennial tufted or rhizomatous plants; blades usually folded and keeled; spikelets with (2) 3-10 florets; glumes shorter than the lemmas; lemmas awnless.

1 Plants strongly rhizomatous, introduced, principal plant in lawns and at other irrigated places at Headquarters; panicles open with conspicuous spreading branches (Kentucky bluegrass) ..... *P. pratensis* L.
1 Plants tufted, not rhizomatous, native, mostly in hills; panicles contracted; the branches strongly ascending and rather inconspicuous in the rather dense spikelets
  2 Spikelets somewhat flattened; lemmas pilose on at least the marginal nerves; plants long-lived; usually in robust bunches, unisexual, apomictic; the florets all pistillate, producing viable seed without fertilization ..... *P. fendleriana*
  2 Spikelets rounded; lemmas at most scabrous, not at all pilose; plants short-lived or long-lived, mostly in small bunches, bisexual, the florets usually with stamens at least when young ..... *P. secunda*

***Poa fendleriana* (Steud.) Vasey** Muttongrass, mutton bluegrass. (*P. longiligula* Scribn. & Williams) Occasional in hills. April through May.

***Poa secunda* Presl.** Sandberg's bluegrass. (*P. sandbergii* Vasey) Occasional to common, mostly in hills. April to mid-June.

Sitanion Raf. Squirreltail

***Sitanion hystrix* (Nutt.) J. G. Smith** Squirreltail. (*Elymus elymoides* [Raf.] Sweezy) Perennials in small tufts, 10-30 (40) cm tall; blades flat or rolled, 1-4 mm wide, often strongly nerved; ligules less than 1 mm long; spikes solitary, terminal, disarticulating at one to several nodes, bristly from the long divergent awns of glumes and lemmas, spikelets 2 per node of the rachis, with 1-6 florets; glumes awnlike their entire length, 3-9 cm long; body of lemmas 7-10 mm long, the awns about as long as those of the glumes. Common but never abundant in black sagebrush communities especially in Antelope Valley, rare to scattered elsewhere. May through June.

Sporobolus R. Br. Dropseed

Warm-season bunchgrasses; leaf sheaths often ciliate on margins near summit; spikelets borne in open or congested panicles, with 1 floret; glumes thin, translucent, shorter than the lemma; lemmas awnless; fruit hard, rounded, falling from the floret at maturity.

1 Panicle open and diffuse, the longer branches to over 10 cm long; leaf sheaths ciliate pilose only on the margin near the collar, the collar glabrous; ventral surface of leaf blades often with a row of pilose hairs to 5 mm long just above the ligule ..... *S. airoides*
1 Panicle contracted or often included in the upper leaf sheath for the entire length, the branches if spreading mostly less than 5 cm long; leaf sheaths ciliate pilose well below the collar, the collar long pilose well around to the opposite side of the culm from the sheath margins; ventral surface without a row of pilose hairs as above
  2 Panicle branches spreading if not confined within the upper sheath; plants 20-50 cm tall ..... *S. cryptandrus*
  2 Panicle densely contracted, nearly cylindrical, the branches appressed ascending even when exserted from the upper leaf sheath; plants mostly 50-100 cm tall ..... *S. contractus*

***Sporobolus airoides* (Torr.) Torr. in Parke** Alkali sacaton. Abundant on a few small areas of valley bottoms, rare on sloping fans. June through September. A warm-season grower, thriving on summer rains. Moderately palatable to cattle and sheep in winter.

***Sporobolus contractus* A. S. Hitchc.** Spike dropseed. Common to abundant locally (especially near the SW1/4 of Sec. 16 T25S R17W in Pine Valley), occasional elsewhere on alluvial slopes. May through September. Responding to summer rains. Moderately palatable to cattle and sheep, and in some winters highly palatable.

***Sporobolus cryptandrus* (Torr.) Gray** Sand dropseed. Widespread, valleys and hills, dominant on some older fans, scattered elsewhere. July through September. Responding to summer rains. Similar to *S. contractus* in palatability to cattle and sheep in winter. *Sporobolus asperifolius* Nees. (*Muhlenbergia asperifolia* [Nees & Mey.] Parodi) was misapplied to plants of *S. cryptandrus* on 1933 plant community type maps of the DER.

Stipa L. Needlegrass

Perennial bunchgrasses; leaf blades often rolled; spikelets borne in panicles, with a single floret; glumes exceeding and enveloping the body of the lemma, not awned; lemmas rather hard, nearly terete, with a hardened, rather sharp base (callus), hairs of the callus usually longer than those of the body of the lemma; awns of lemmas long, often bent, the lowest segment often twisted.

1 Awns about 1-2 cm long; lemmas densely pilose with hairs 2-3 mm long; plants 10-30 cm tall ..... *S. parishii*
1 Awns over 2 cm long; lemmas glabrate to sparsely hairy, the hairs less than 2 mm long; plants sometimes over 30 cm tall
  2 Awns plumose on lowest segments, 3-4 (5) cm long; ligules fringed-ciliolate, about 0.5 mm long; collars densely pilose ..... *S. speciosa*
  2 Awns glabrous or scabrous, 4-16 cm long; ligules not ciliolate, 0.2-5 mm long; collars and sheaths glabrous or scabrous
    3 Glumes 7-11.5 mm long; awns of lemmas 4-7.5 cm long, flexuous, not strongly bent; panicles narrow with ascending to appressed branches .... *S. arida*
    3 Glumes 15-20 (35) mm long; awns of lemmas 6-16 cm long, strongly bent; panicles spreading at maturity with widely divergent branches ..... *S. comata*

***Stipa arida* Jones** Mormon needlegrass. Infrequent to occasional, hills, often in colluvium. Mid-May through June.

Stipa comata* Trin. & Rupr. var. *comata Needle-and-thread. Dominant and codominant on areas of deep coarse sandy soils on flats and valley bottoms, and at the foot of steeper slopes, and on finer textured soils on upper benches and in hills in and near the pinyon-juniper zone. Mid-May through June.

***Stipa speciosa* Trin. & Rupr.** Desert needlegrass. Locally common among rocks on Warm Cove Ridge. May through July.

***Stipa parishii* Vasey var. *depauperata* Jones** (*S. coronata* Thurb. var. *depauperata* [Jones] A. S. Hitchc.) Infrequent to occasional in hills. May through June. Plants of the DER and other places in Millard to Tooele Counties, UT, and west to central Nevada represent the extreme for the species in small size (12-25 cm tall), short leaf blades (3-15 cm long), and short awns (1-1.5 cm long). The collars are glabrate to ciliate and not with tufts of long crinkley hairs. Plants with these features are reported by Hitchcock (1951) and Cronquist and others (1977) to be linked through numerous intermediate plants to *Stipa coronata* var. *coronata*, which at its maximum is: 1-2 m tall, with leaf blades 30-50 cm long, with awns 25-42 cm long, and with tufts of long crinkley hairs at the collars of leaves.

POLEMONIACEAE; PHLOX FAMILY

Annual to perennial herbs or subshrubs; leaves opposite or alternate, simple to pinnatifid; corolla united, 5 lobed; stamens 5; stigmas mostly 3-lobed; fruit a capsule.

1 Leaves entire, opposite, often crowded, linear or nearly so; plants herbaceous perennials ..... *Phlox*
1 Leaves not entire, alternate or opposite; plants various
  2 Some of the lower leaves opposite or appearing whorled, palmatifid into linear or needlelike segments, the segments sometimes appearing as fascicles or whorls of filiform leaves; plants perennial subshrubs ..... *Leptodactylon*
  2 Leaves alternate, simple to pinnatifid; plants annual to perennial herbs ..... *Gilia*

Gilia R. & P. Gilia

With features of the family and as listed in the key. In addition to the taxa listed below *Eriastrum sparsiflorum* (Eastw.) Mason (*Gilia sparsiflora* Eastw.; *Welwitchia wilcoxii* Rydb.; *W. floccosa* [A. Gray] Rydb. misapplied) might be expected on the DER. The name *Welwitchia* is found on old study sheets of plots on the DER. However, it is more likely that the plants referred to as *Welwitchia* are one of the following annual species of *Gilia*.

1 Plants perennial, sometimes appearing annual; leaves entire or trifid or with up to 7 linear entire segments ..... *G. congesta*
1 Plants annual; leaves various, but not as above
  2 Flowers borne in an open inflorescence, at least some borne on conspicuous pedicels; corollas 4-15 mm long; plants mostly 5-20 cm tall; leaves pinnately lobed to pinnatifid
    3 Leaves pinnately lobed or merely toothed, the lobes mostly entire; corollas 4-6 mm long, the lobes often tridentate; plants without tomentum; gland-tipped hairs of the inflorescence not purplish or blackish ..... *G. leptomeria*
    3 Leaves pinnatifid, appearing compound, the primary divisions often toothed or lobed; corollas (5) 7-12 (15) mm long, the lobes not tridentate; plants with some cobwebby tomentum at least in axils of leaves or inflorescence with black or dark purplish gland-tipped hairs
      4 Plants with some cobwebby tomentum on the leaves or at least in the axils of leaves, mostly on hills ..... *G. inconspicua*
      4 Plants with dark gland-tipped hairs, without any cobwebby tomentum, mostly in Pine Valley ..... *G. hutchinsifolia*
  2 Flowers sessile or nearly so in a congested inflorescence, or axillary; leaves entire to toothed or lobed; corollas 4-6 mm long; plants 1-5 (10) cm tall
    5 Leaves entire or toothed; lower flowers solitary in axils of leaves; stems leafy ..... *G. depressa*
    5 Leaves toothed to pinnatifid; flowers all in terminal clusters; the terminal cluster closely subtended by a cluster of leaves that are about as large as those at the base of the plant; stems mostly leafless between the basal and terminal cluster of leaves ..... *G. polycladon*

***Gilia congesta* Hook.** Ballhead gilia. (*Ipomopis congesta* [Hook.] V. Grant) With two varieties on the DER.

1 Leaves trifid to pinnatisect or a few entire, mostly with at least some cobwebby hairs; plants perennial but sometimes appearing annual ..... var. *congesta*
1 Leaves entire, glabrous to floccose-tomentose on lower side; plants strongly perennial ..... var. *crebrifolia*

Var. *congesta* Occasional in valleys. May through June.

Var. *crebrifolia* (Nutt.) Gray Locally common on Tunnel Springs Mountain. May through June. Disjunct from southwestern Montana and northern and western Wyoming, or perhaps the plants of Tunnel Springs Mountain, Wah Wah Mountains, and Mountain Home Range of Millard and Beaver Counties represent an unnamed variety.

***Gilia depressa* Jones** Depressed gilia. (*Ipomopsis depressa* [Jones] V. Grant) Occasional in some years in Pine Valley, most specimens seen are from within a half kilometer of Headquarters. May through June.

***Gilia hutchinsifolia* Rydb.** Common in most years on sandy ground in valleys. May through June.

***Gilia inconspicua* (J. E. Sm.) Sweet.** (*G. opthalmoides* A. Brand; *G. sinuata* Dougl.) Occasional to common at least in some years, mostly in hills. May through June.

***Gilia leptomeria* Gray** Great Basin gilia. Occasional, hills and washes. May through June.

***Gilia polycladon* Torr. in Emory** (*Ipomopsis polycladon* [Torr.] V. Grant) Infrequent but widespread, mostly in washes and on disturbed ground. May through June.

Leptodactylon H. & A. Prickly Phlox; Prickly Gilia

Leptodactylon pungens* (Torr.) Nutt. var. *pungens Prickly phlox. Perennial plants (shrubs or subshrubs) more or less woody at base, 10-40 cm tall; leaves sessile, palmately parted into needlelike divisions, lower ones opposite, the upper ones opposite, subopposite, or alternate, with smaller leaves fascicled in the axils of the primary ones; flowers sessile, solitary or a few in a cluster, showy; corolla white, cream colored, or purplish in

the throat, 15-20 mm long, the tube narrow, the lobes often spirally closed during the day. Infrequent, scattered, mostly along washes. May through June.

Phlox L. Sweet William; Phlox

Perennial herbs; leaves sessile, entire, opposite; flowers solitary or in small clusters; corollas white, pink, or bluish.

1 Plants not tufted or mat forming; stems more or less ascending or erect; principal leaves (1) 2-3 (4) cm long, more or less well spaced on the stem and not concealing the internodes; flowers evidently pediceled; styles 6-25 mm long . . *P. longifolia*
1 Plants tufted, forming mounds or mats; stems more or less prostrate or sprawling; principal leaves 2-20 mm long, crowded on the stems, sometimes concealing the internodes; flowers sessile or nearly so; styles various
  2 Plants densely pubescent with villose or cobwebby hairs, densely pulvinate caespitose; leaves 2-5 mm long; corolla lobes 3-5 mm long . . . . . *P. muscoides*
  2 Plants glabrous or sparsely pubescent, loosely mat-forming; leaves 8-30 mm long; corolla lobes 5-8 mm long . . . . . *P. austromontana*

Phlox austromontana **Cov.** Desert phlox. Occasional, hills and washes. Late April to mid-June.

Phlox longifolia **Nutt.** The specimens seen are from the Warm Cove-Halfway Hills area. Plants from the DER are a short-leafed phase and are referable to var. *brevifolia* (Gray) Gray.

Phlox muscoides **Nutt.** (*P. bryoides* Nutt.; *P. caespitosa* Nutt. spp. *muscoides* Brand.) Occasional to common on fans and hills. March through September.

POLYGALACEAE; MILKWORT FAMILY

Polygala L. Milkwort; Polygala

Low shrubs or subshrubs with spine-tipped twigs (about 5-20 cm tall on the DER); leaves alternate, 8-20 mm long; flowers irregular, borne on or near young spines on slender pedicels; sepals 5, free, the 2 inner ones (wings) much larger than the outer ones, petaloid; petals 3, united into a more or less tubular corolla; stamens mostly 8, the filaments united.

1 Flowers about 3 mm long, yellowish to cream, or the sepals purplish at the apex; twigs woody above ground level not dying back to base, covered with whitish hairs, the hairs dense enough to conceal the epidermis; leaves linear spatulate or oblanceolate, 1-3 mm wide, moderately pubescent, not ciliolate . . . . . *P. acanthoclada*
1 Flowers 6-10 mm long; the sepals bright pink-purple, the corolla yellowish; twigs herbaceous or nearly so, and dying back to the base, gray-green, glabrate to moderately puberulent with spreading short hairs, the hairs not dense enough to conceal the epidermis; leaves obovate to elliptic-oblanceolate, 2-6 mm wide, glabrate to puberulent, often sparsely ciliolate . . . . . *P. subspinosa*

Polygala acanthoclada **Gray** Thorn polygala. Infrequent but widespread, hills and upper parts of fans in Pine Valley. June through September.

Polygala subspinosa **Wats.** Spiny polygala. Rare but widespread, hills and upper parts of fans. Late April through June.

POLYGONACEAE; BUCKWHEAT FAMILY

1 Leaves without scarious sheathing stipules; plants widespread . . . . . *Eriogonum*
1 Leaves with scarious sheathing stipules; plants known only from on and around the Pine Valley Playa . . . . . *Polygonum*

Eriogonum Michx. Wild Buckwheat; Eriogonum

Annual or perennial herbs or shrubs; leaves basal or alternate, simple, entire; inflorescence various; flowers borne few together in involucres, each with a threadlike pedicel, the pedicels included or exserted from the involucre; perianth of a single whorl, parted or deeply cleft into 6 small but more or less petaloid segments (tepals); stamens 6-9; fruit an achene.

1 Plants annual; inflorescence usually dichotomously or trichotomously branched or umbellike; leaves all basal
  2 Leaves greenish or yellow-green on both sides, hirsute; stems, branches, and pedicels with tack-shaped glandular hairs; tepals yellow, densely pubescent externally; involucres on threadlike peduncles up to 15 mm long . . . . *E. howellianum*

2 Leaves whitish or grayish at least on one side, tomentose or floccose; plants not glandular; tepals white, pinkish, or yellow, but not pubescent externally; involucres sessile or on short (1-3 mm) peduncles
3 Stems and branches tomentose; involucres sessile; tepals white or pinkish ..... *E. palmerianum*
3 Stems and branches glabrous or nearly so; involucres sessile or short-peduncled; tepals white, pinkish or yellowish
4 Tepals yellowish or cream; fruit prominently winged ..... *E. hookeri*
4 Tepals white or pinkish; fruit not strongly winged ..... *E. cernuum*
1 Plants perennial; inflorescence headlike or branched as above
5 Leaves alternate, not all basal; upright shrubs with stems woody above ground level; inflorescence trichotomously branched; the branches tomentose or floccose ..... *E. microthecum*
5 Leaves all basal; stems not woody above ground level; inflorescence various
6 Inflorescence open, umbellike, trichotomously long-branched; stems and branches glabrous; plants 15-30 cm tall or taller, not mat-forming ... *E. eremicum*
6 Inflorescence headlike; stems tomentose or floccose; plants 1-15 cm tall, rarely taller, mound-forming or mat-forming dwarf shrubs with woody stems at ground level
7 Leaves ovate to orbicular, about as wide as long, mostly over 4 mm wide, constricted to a conspicuous petiole; scapes 2-20 cm tall; tepals glabrous ..... *E. ovalifolium*
7 Leaves linear to elliptic, or at least not over 4 mm wide, sessile or gradually tapered to an indistinct petiole; scapes 0.5-5 cm tall, sometimes not extended beyond the leaves; tepals pubescent
8 Tepals white; leaves mostly with acute tips; plants villous, the epidermis of scapes visible through the spreading hairs ..... *E. villiflorum*
8 Tepals yellow; leaves with rounded tips; plants tomentose-floccose, the epidermis of scapes obscured or nearly so by the dense interwoven hairs ..... *E. shockleyi*

Eriogonum cernuum **Nutt. var. *viminale* (Stokes) Reveal in Munz** Nodding eriogonum. Occasional to common in some years, valleys and washes. June through September. Responding to summer and early fall precipitation.

Eriogonum eremicum **Reveal** Desert range eriogonum. Occasional on shallow, rocky soils in hills, mostly on the north half of the DER, endemic to the DER and surrounding parts of southwestern Millard County. The type specimen (N. Holmgren and others 2247) is from the DER. June through September.

Eriogonum howellianum **Reveal** Howell's eriogonum. (*E. glandulosum* [Nutt.] Nutt. misapplied) Occasional to locally common in some years (not seen every year), fans, washes, roadsides, and low hills between Pine Valley and Tunnel Springs Mountain, endemic to desert ranges of western Utah. July through October. Responding to summer and early fall precipitation.

Eriogonum hookeri **Wats.** Occasional or at least infrequent in most years, some years rather common especially on the broad fan of Mountain Home Wash east of Warm Cove Ridge. June through September. Responding to summer and early fall precipitation.

Eriogonum microthecum **Nutt.** Most often seen as a common associate of *Artemisia nova*, more persistent within the crown of *Artemisia* and possibly reduced by sheep grazing in winter. July through September.

Eriogonum ovalifolium **Nutt. var. *ovalifolium*** Cushion eriogonum. Occasional, mostly in hills and upper parts of fans. May through June.

Eriogonum palmerianum **Reveal in Munz** The one specimen seen is from the gravelly wash bottom of Mountain Home Wash near Warm Cove Ridge. July through September. Responding to summer and early fall rains.

Eriogonum shockleyi **Wats. var. *candidum* (Jones) Reveal** Shockley wild buckwheat. Occasional or locally common in hills and upper parts of fans. May through June.

Eriogonum villiflorum **Gray** Villous-flowered eriogonum. Occasional or locally common, hills and especially Tunnel Springs Mountain. April through June.

Polygonum L. Knotweed

Polygonum aviculare **L.** Common knotweed. Annual herbs; leaves simple alternate, entire, 5-20 mm long, lanceolate, subtended by scarious sheathing stipules, the sheaths

soon torn; flowers 1-5 in axillary clusters, inconspicuous, the perianth of a single whorl, 2-3 mm long, greenish with pinkish to purplish margins; stamens 8; fruit an achene. Introduced from the Old World, locally common on bottoms of bulldozed basins at the edge of Pine Valley Playa.

POLYPODIACEAE; COMMON FERN FAMILY

Cheilanthes Moore

***Cheilanthes feei* Moore** Fee lipfern. Perennial herbs; leaves arising from a scaly caudex-like subterranean stem, unfolding with fiddle-head shape as they mature; the petioles 3-10 cm long, dark purplish brown, the blades 3-13 cm long, pinnately decompound, the leaflets pubescent with spreading whitish or tawny multicellular hairs; flowers lacking; reproduction by spores, the spores grouped in sporangia, borne on the lower margins of leaflets. Rare among rocks and in rock crevices, hills.

PORTULACACEAE; PURSLANE FAMILY

Lewisia Pursh
Bitterroot; Lewisia

***Lewisia rediviva* Pursh** Bitterroot. Perennial herbs from thickened fleshy fascicled roots; leaves basal, fleshy, succulent, simple, entire, linear or at least narrow, nearly terete, 1.5-3 cm long, about 2-4 mm wide; flowers solitary and terminal on scapes 2-5 (7) cm long; scapes with a whorl of bracts, jointed just below the bracts; sepals petaloid, these and the petals about 16-30, 10-35 mm long, white or pinkish; stamens 20-50; fruit a capsule. The one specimen seen is from near the northern boundary of the DER on Tunnel Springs Mountain.

RANUNCULACEAE; BUTTERCUP FAMILY

1 Flowers solitary and terminal on leafless scapes; petals pinkish or pink-purple, none spurred; sepals not spurred; fruit of numerous achenes ..... *Ranunculus*
1 Flowers 3-several in a raceme; petals and sepals blue, the uppermost sepal projected into an obvious spur; fruit of 3 follicles ..... *Delphinium*

Delphinium L.
Larkspur

***Delphinium andersonii* Gray** Anderson larkspur. Perennial glabrate herbs, 20-40 cm tall, from fascicled roots; leaves palmatifid, distinctly petioled, basal and alternate, reduced in size and number upward on the stems; flowers irregular, the sepals 5, petaloid, the upper one strongly projected into a spur 12-18 mm long; petals in 2 sets of 2 each, the lower 2 narrowed to a claw, the upper 2 prolonged into the spur of the upper sepal; stamens many. Infrequent, mostly in hills. May through June.

Ranunculus L.
Buttercup

***Ranunculus juniperinus* Jones** (*Beckwithia juniperina* [Jones] Heller) Perennial glabrous herbs, 5-15 (20) cm tall, scapose; leaves palmatifid, distinctly petioled, all basal; flowers regular; sepals greenish toward the base, petaloid toward the apex; petals about 12-15 mm long; stamens numerous; achenes numerous, flattened, borne in a headlike cluster on a receptacle. Infrequent or occasional in hills and especially on Tunnel Springs Mountain in shade and duff of pinyon and juniper. March to mid-May, often flowering at the edge of melting snow.

ROSACEAE; ROSE FAMILY

Shrubs (on DER); leaves alternate or basal, sometimes fascicled, sessile or gradually tapered to an indistinct petiole; flowers and fruit extremely variable.

1 Plants not over 15 cm tall; leaves in basal rosettes ..... *Petrophytum*
1 Plants over 15 cm tall; leaves not in basal rosettes
  2 Leaves entire or with a few inconspicuous teeth, not over 6 mm wide; fruit various
    3 Petals lacking; fruit an achene with a plumose style 1-3 cm long; leaves so tightly rolled (revolute) that the lower surface is hidden except sometimes for the midrib, not deciduous in winter or dry part of summer, rather leathery, dark green and glabrous or glabrate on the upper (exposed) surface .... *Cercocarpus*
    3 Petals 3.5-5 mm long; fruit a drupe, the style less than 1 cm long, not plumose; leaves flat, not rolled, deciduous by winter and perhaps by drought in some years, not leathery, green, usually sparsely pubescent on both sides ..... *Prunus*

2 Leaves lobed or if only toothed then regularly and conspicuously so and usually some over 6 mm wide; fruit an achene
4 Leaves (3) 5 lobed, glandular; petals 5-9 mm long, showy individually; achene with a plumose tail 2-6 cm long ..... *Cowania*
4 Leaves toothed on the upper half, not glandular; petals about 2 mm long; achenes without plumose tails ..... *Holodiscus*

Cercocarpus H. B. K. Mountain-Mahogany

***Cercocarpus intricatus* Wats.** Littleleaf cercocarpus, littleleaf mountain-mahogany, rockbrush. (*Cercocarpus ledifolius* Nutt. var. *intricatus* [Wats.] Jones) Shrubs 50-100 (150) cm tall, intricately branched; leaves 3-18 mm long; flowers inconspicuous, spicy fragrant; stamens 10-20. Common to dominant, on steeper rocky hills and especially on Tunnel Springs Mountain in the pinyon-juniper zone. May through June. Palatable sheep feed in winter.

Cowania D. Don Cliffrose

***Cowania mexicana* D. Don var. *stansburiana* (Torr.) Jeps.** Stansbury cliffrose. (*C. stansburiana* Torr.) Shrubs, 0.6-3 m tall, with shreddy bark and glandular branchlets; leaves 3-15 mm long, fan-shaped, with 3-5 lobes, glandular punctate and green above, white tomentose beneath; petals white, cream, or yellow; each flower usually producing (3) 5 achenes. Infrequent, scattered in rocky hills and near drainage channels in the upper parts of some alluvial fans. June. Some plants hedged by sheep in winter and by antelope.

Holodiscus Maxim. Mountain Spray

***Holodiscus dumosus* (Nutt.) Heller** (*H. microphyllus* Rydb.; *Sericotheca dumosa* [Nutt.] Rydb.) Shrubs 0.5-1.5 m tall; leaves 5-32 mm long, 2-23 mm wide, obovate to elliptic, toothed on the upper half, more or less wedge-shaped on the mostly entire lower half; flowers numerous in panicles, individually inconspicuous but the densely flowered panicles showy; petals white, cream, or pinkish, about 2 mm long. Known from Tunnel Springs Mountain near northern boundary of DER, north side of rock outcrops. June through July.

Petrophytum Nutt. in T. & G.

***Petrophytum caespitosum* (Nutt.) Rydb.** Tufted rockmat. (*Spiraea caespitosa* Nutt. in T. & G.; *Eriogyna caespitosa* [Nutt.] Wats.) Plants woody at base, forming pale-colored mats or mounds, the woody stems remaining on rocks or at ground level, aerial stems scapose, not woody; leaves in basal rosettes, simple, entire, 3-17 mm long, 1.5-4.5 mm wide, spatulate to obovate, pilose on one or both sides or rarely glabrous; scapose peduncles 0.5-10 cm tall, with bractlike leaves; flowers in a 5-25 mm long spikelike panicle, small but showy collectively; petals about 1-3 mm long, white; fruit of usually 5 follicles. Occasional on rock faces of Tunnel Springs Mountain and on white volcanic rock outcrops to the south and east of the mountain. August through October.

Prunus L. Cherry; Plum; Almond

***Prunus fasciculata* (Torr.) Gray** Desert almond, desert peachbrush. (*Emplectocladus fasciculatus* Torr.) Shrubs 30-150 cm tall; branchlets ashy or grayish, pubescent, more or less thornlike; leaves 5-25 mm long, 1-6 mm wide, entire or with a few small teeth near the apex, short-pointed at apex; petals white to cream; fruit about 7-10 mm long, ovoid, hairy. Scattered on steep rocky slopes of canyons and sometimes hillsides and abundant in many washes across the slopes of fans and well out into the valleys. May through June. At least a few plants blossom each year, but fruit production is rather rare. Not browsed in winter, but leaves and twigs provide a substantial proportion of the summer diet of antelope. Tent caterpillars (*Malacosoma* sp.) are usually present on a few shrubs in the early spring, and in some years they are so numerous as to delay the appearance of foliage for a month or more. The shrubs have shown no long-term ill effect from such severe defoliation.

RUBIACEAE; MADDER FAMILY

Galium L. Bedstraw; Cleavers

Galium multiflorum* Kellogg var. *multiflorum Shrubby bedstraw. Perennial plants more or less woody at the base, 10-30 cm tall; leaves in whorls of 4, sessile, linear to broadly ovate, mostly short-pointed at apex, 5-20 mm long, the midrib prominent; flowers unisexual, small, inconspicuous, few in the axils of leaves, with short pedicels; corolla united, 2-4 mm wide; ovary and fruit covered with spreading straight or flexuous hairs. Infrequent in rocky outcrops and rocky places on Tunnel Springs Mountain. May through June.

SAXIFRAGACEAE; SAXIFRAGE FAMILY

1 Plants scapose forbs ..... *Heuchera*
1 Shrubs with alternate leaves ..... *Ribes*

Heuchera L. Alumroot; Heuchera

***Heuchera rubescens* Torr. in Stansb.** Red alumroot. Herbs 5-30 cm tall, clothed at the base with persistent leaf bases; leaves all basal, simple, the petioles 1-6 cm long, the blades 0.7-4 cm long, orbicular to broadly ovate, cordate or truncate at the base, palmately lobed, the primary lobes often again lobed, dentate or crenate; flowers in racemose or spicate panicles; floral tube short, reddish or pinkish, bearing small calyx lobes, petals, and stamens; petals 3-4 mm long, white; stamens exserted; fruit a capsule, 4-6 mm long. Infrequent or locally common in crevices of rock outcrops, mostly on north exposures, specimens seen are all from Tunnel Springs Mountain. May through June.

Ribes L. Currant; Gooseberry

***Ribes cereum* Dougl.** Wax currant. Shrubs 30-150 cm tall; twigs pilose-villous and stipitate-glandular; leaves simple, the petioles 4-22 mm long, the blades 5-30 mm long, orbicular to reniform, cordate or truncate, with 3-7 shallow lobes, the lobes crenate or dentate; inflorescence a raceme with 2-3 flowers; floral tube 4-11 mm long, pinkish, bearing small petaloid sepals, petals, and stamens; fruit a berry, crowned by the withered flower. Rare, rocky canyons and hillsides of Warm Cove Ridge and Tunnel Springs Mountain. May through June. Often included in Grossulariaceae (currant or gooseberry family).

SCROPHULARIACEAE; FIGWORT FAMILY

Annual or perennial herbs; leaves extremely variable; corolla united, tubular, mostly irregular; fertile stamens 4; fruit a 2-chambered capsule.

1 Leaves opposite, simple, entire to toothed; fertile stamens 4, a 5th stamen modified into a sterile staminode; plants glabrous to puberulent, or with viscid-villous hairs ..... *Penstemon*
1 Leaves alternate, at least some deeply lobed to pinnatifid or trifid; stamens 4, staminode lacking; plants mostly with viscid-villous hairs at least in the inflorescence
  2 Leaves pinnately lobed to pinnatifid, with more than 7 lobes, 3-15 cm long, the basal ones tufted and exceeding the inflorescence, the lobes rounded, crenate, the rounded teeth often with smaller whitish-margined dentate teeth; corolla more showy than the calyx or bracts ..... *Pedicularis*
  2 Leaves 3-5 cleft or 3-5 lobed, the lower ones sometimes entire, the basal tuft lacking or not exceeding the inflorescence, the linear or acute lobes or segments entire or toothed but not crenate
    3 Plants perennial; inflorescence red, lower leaves often entire, the upper ones 3-7 lobed or cleft, the divisions narrowly triangular to linear but hardly filiform; stems not branched above the base ..... *Castilleja*
    3 Plants annual; inflorescence not red; lower and upper leaves dissected, the segments more or less linear or filiform; stems branched in the inflorescence ..... *Cordylanthus*

Castilleja Mutis Indian Paintbrush

Inflorescence with red showy bracts and calyces; corollas narrow, greenish and comparatively inconspicuous.

1 Plants 5-15 cm tall; the greenish corolla (25) 30-40 mm long, well exserted beyond the linear to lanceolate, reddish bracts, and conspicuous in the rather short broad inflorescence ..... *C. scabrida*
1 Plants 20-30 cm tall; the greenish corolla 20-30 (35) mm long, mostly or nearly concealed in the lanceolate to broadly ovate reddish bracts; inflorescence short and broad at first, later elongating ..... *C. chromosa*

***Castilleja scabrida* Eastw. var. *barnebyana* (Eastw.) N. Holmgren** Dolomite Indian paintbrush. (*C. barnebyana* Eastw.) Infrequent to locally common, Tunnel Springs Mountain, crevices of rocks and rocky (dolomite) slopes and ridges, usually in pinyon-juniper and littleleaf mountain-mahogany communities. April through June.

***Castilleja chromosa* A. Nels.** Desert Indian paintbrush. (*C. angustifolia* [Nutt.] G. Don var. *collina* [A. Nels.] Garrett; *C. a.* var. *dubia* A. Nels.) Infrequent or occasional in hills. April through June.

Cordylanthus Nutt. Birdbeak; Clubflower

Cordylanthus kingii* Wats. var. *kingii King's birdbeak. (*Adenostegia kingii* [Wats.] Greene) Annual herbs 5-15 (20) cm tall, from a yellowish taproot; herbage pubescent; leaves cleft into narrow divisions; flowers in dense terminal clusters; calyx cleft to the base in front and extending behind the corolla as a bractlike structure with a bifid apex; corolla 2-lipped, dull pinkish-purple, 16-20 mm long, subtended by a solitary 5-7 parted bract. The one specimen is from a black sagebrush-Greene's rabbitbrush community in the bottom of Antelope Valley at the western edge of the DER. July through September.

Pedicularis L. Lousewort

***Pedicularis centranthera* Gray in Torr.** Dwarf lousewort. Perennial herbs, 5-15 cm tall; leaves nearly linear in outline, deeply lobed to pinnatifid, rather crowded, the petioles 1-4 cm long or longer, the blades 2-10 cm long; flowers in dense clusters, the clusters often overtopped by leaves; corollas well exserted from the calyx, 25-30 mm long, strongly 2-lipped, the upper lip arched and longer than the lower one, dull pink-purple. Infrequent or locally common, Tunnel Springs Mountain, pinyon-juniper woodlands. April through May.

Penstemon Mitch. Beardtongue; Penstemon

With features of the family and key. Note: Plants with white corollas are rarely encountered in most taxa.

1 Plants 40-100 cm tall or taller, glabrous and glaucous below the inflorescence; leaves all conspicuously toothed with coarse teeth; corollas 22-35 mm long, whitish or pinkish with darker lines; staminode exserted, shaggy-bearded; capsules 10-14 mm long ..... *P. palmeri*

1 Plants 3-20 (30) cm tall, glabrous or pubescent; leaves entire or with a few small teeth; corollas 8-20 mm long, variously colored; staminode various

2 Plants glabrous and glaucous; the corollas occasionally obscurely glandular externally; staminode pale, flat and somewhat recurved, glabrous or sparsely pubescent; corollas pink-lavender ..... *P. confusus*

2 Plants pubescent either throughout or at least in the inflorescence, the stems often with retrorse hairs; corollas glandular to pubescent externally; staminode pubescent

3 Lower leaves glabrous, linear to linear-oblanceolate, narrower or as wide as those of the inflorescence, 3-5 (7) cm long, those of the inflorescence glabrate to puberulent, a few more or less toothed; stems puberulent below the inflorescence; inflorescence densely pubescent with flattened viscid hairs; corollas 8-11 mm long, shorter than the subtending leaves or bracts, violet with darker violet lines, with dense tufts of pale long hairs internally or near the mouth; anthers exserted at least to the sinuses of the corolla lobes, widely spreading from each other at maturity; staminode exserted from the corolla, bearded with white or pale hairs ..... *P. concinnus*

3 Lower and upper leaves puberulent, entire, the lower ones wider than linear-oblanceolate, mostly as wide or wider than those of the inflorescence; inflorescence glandular or not; corollas 10-20 mm long, shorter or longer than the subtending leaves or bracts, blue, without dense tufts of pale long hairs; anthers various; staminode included or just equaling the corolla, variously bearded

4 Inflorescence with viscid flattened hairs; anthers remaining horseshoe-shaped even in age, deeply included in the corolla, just equaling the tube or barely exserted into the limb; staminode included in the limb of the corolla, densely bearded with bright yellow or orange-yellow, long hairs; corolla 10-15 mm long, glandular externally, glabrous or sparsely pubescent internally ..... *P. nanus*

4 Inflorescence densely puberulent but without viscid hairs; anthers widely spreading, about equaling the corolla; staminode about equaling the corolla, moderately bearded with white or pale yellow hairs; corolla 14-20 mm long, glandular externally, sparsely pubescent internally in lines with short yellowish hairs ..... *P. dolius*

***Penstemon concinnus* Keck.** Desert range beardtongue. Rare (on DER) west of and west side of Tunnel Springs Mountain; the type (Cottam 5634) from Tunnel Springs Mountain, endemic to southwestern Millard County and western Beaver County, UT, and possibly adjacent Nevada. May through June.

***Penstemon confusus* Jones** Pale penstemon. Occasional, hills, fans, and gravelly washes, mostly on or near Tunnel Springs Mountain. May through June.

***Penstemon dolius* Jones ex Pennell** Jones penstemon. Infrequent or occasional, the few specimens seen are from Halfway Summit and Tunnel Springs Mountain. May through June.

***Penstemon nanus* Keck** Dwarf beardtongue. Occasional, hills and upper parts of fans, endemic to Beaver and Millard Counties, UT, around Tunnel Springs Mountain; the type (Plummer 7413) from the DER. May through June.

***Penstemon palmeri* Gray** Palmer penstemon. Infrequent along raw banks of Mountain Home Wash. May through June.

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Keys, brief descriptions, habitat data, and pertinent synonomy are provided for the vascular flora of the Desert Experimental Range to assist in range, wildlife, ecological, and other studies conducted on the area.

KEYWORDS: vascular plants, Desert Experimental Range

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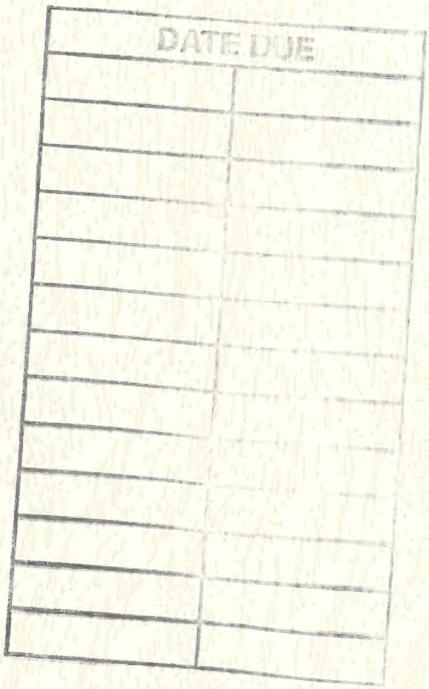
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